TABLE OF CONTENTS

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This report summarizes the work done by the rulemaking task team in support of the overall arac fuel tank inerting harmonization working group task.

1.0 RULEMAKING TEAM'S TASK

The rulemaking team's task was defined in accordance to the FTIHWG's tasking statement. It was defined as follows:

1. To review existing regulations/advisory material/continued airworthiness instructions regarding the subject of eliminating or reducing the flammable environment in airplane fuel tank systems.
2. To prepare and coordinate within the HWG a regulatory text, for use in new rulemaking initiatives by the FAA, that would eliminate or significantly reduce the flammable environment in airplane fuel tank systems. The tasking statement stated that the recommendation proposal would be based on achieving the lowest flammability level that could be provided by [an inerting system] design that would meet FAA regulatory evaluation requirements.
3. For all system concepts recommended, develop and propose guidance material that describes the necessary analysis and/or testing that may be required to show compliance with the new regulatory text for certification and continued airworthiness.

2.0 METHODOLOGY USED TO ACHIEVE THE TASK

The methodology used by the rulemaking task team to achieve the task was as follows:

<u>Basic Assumptions</u>:

The rulemaking team assumed that both ground-based inerting and on-board inerting designs need to be certified and utilized. This assumption was made because the practicality of either design was unknown.

1. Determination of 14 CFR sections to be evaluated

The team determined which Title 14 of the U.S. Code of Federal Regulations (14 CFR) sections might be impacted by the two inerting-designs by examining the aircraft utilization. The team confirmed that, at a minimum, aircraft certification, aircraft maintenance and operational approval and airport facilities may be impacted. The team concluded that an assessment of the major issues affecting the 14 CFR could easily be transferred to a JAR assessment if final rulemaking was pursued.

2. Analyses of the regulatory impact on existing 14 CFR codes

The team then used the design concepts, developed by the other FTIHWG teams, to analyze the impact on the existing regulations/advisory material/continued airworthiness instructions. This analysis was done throughout the FTIHWG process in order to ensure that all design issues were accounted for in the final 14 CFR change recommendations.

3. Development of guidance material

Guidance material was developed to support the 14 CFR change proposals.

4. Flammability regulatory text proposals

Finally, regulatory text proposals that could be used by the FAA to regulate an airplane's fuel tank environment on the level of flammability reduction achieved by a practicable inerting system design concept were proposed to the Harmonization Working Group (HWG). The rulemaking team highlighted the pros and cons of each proposal, including its possible certification interpretations and its capability to allow an inerting system as an acceptable means of compliance.

5. Certification Cost Assessment

The regulatory team estimated a certification cost for both ground and on-board inerting systems. The costs were then inputted into the regulatory evaluation cost forecast.

6. HWG flammability regulatory text recommendation

The HWG was tasked to decide which proposal, if any, to recommend. The HWG's recommendation would be based on the outcome of the cost/benefit evaluation performed by the FTIHWG.

3.0 14 CFR EVALUATION

3.1 DETERMINATION OF 14 CFR SECTIONS TO BE EVALUATED

The team identified and conducted a review of the 14 CFR sections relating to aircraft certification, aircraft maintenance and operational approval and airport facilities. The 14 CFR 1-1-00 Edition as published by the U.S. Federal Aviation Administration, DOT was used as the review basis.

The European Joint Aviation Requirements (JARs) were not used as a reference basis because of the lack of JAR operational regulatory (JAR ops) expertise on the rulemaking team.

The rulemaking team concluded that the lack of JAR ops expertise and the lack of an in-depth review of the JARs did not deter the overall review objectives. The team knew that the 14 CFR and JAR part 25 aircraft certification requirements are very similar and that any differences are already documented. The team also knew that the intent of both 14 CFR and JAR operational regulations are similar. Therefore, the team decided that JAR experts could evaluate their codes, as appropriate, if a clear and concise explanation of the regulation assessment is provided.

Aircraft Certification

The rulemaking team assessed:

- 14 CFR part 21 - Aircraft -Certification Procedures for Products and Parts
- 14 CFR part 25 -Airworthiness Standards: Transport Category Airplanes

Both of these sections are utilized when certifying a Transport Category airplane and were the affected by the FAA's ignition source prevention activity (SFAR No. 88).

Other aircraft type certification standards such as 14 CFR part 23 -Airworthiness Standards: normal, utility, acrobatic and commuter category airplanes, were not assessed. The rulemaking team decided that the FAA could use the recommendations made for 14 CFR part 21 and 14 CFR part 25 to assess and to modify, if necessary, similar 14 CFR parts.

Maintenance and Operational Approval

The rulemaking team identified and assessed the following 14 CFR sections that relate to aircraft maintenance and operations:

- Part 43 - Maintenance, Preventative Maintenance, Rebuilding, and Alteration
- Part 91 - General Operating and Flight Rules
- Part 121 - Operating requirements: Domestic, flag and supplemental operations
- Part 125 - Certification and operations: Airplanes having a seating capacity of 20 or more passengers or a maximum payload capacity of 6,000 or more
- Part 129 - Operations: Foreign air carriers and foreign operators of U.S.-registered aircraft engaged in common carriage

The part 43 assessment was carried out independently.

The other parts were assessed using part 121. That is, the team assumed that any change applicable to part 121 could be read over to parts 91/125/129. This assumption was made based on FAA's ignition source prevention activity (NPRM 99-18/SFAR No. 88 effective June 6, 2001).

The team did not consider Part 135 - operating requirements: Commuter and On-Demand Operations. The rulemaking team decided that the FAA could adapt the recommendations made for 14 CFR part 91/121/125/129 to other similar 14 CFR parts.

<u>Airport Facilities</u>

The rulemaking team identified and assessed 14 CFR part 139: Certification and Operations: Land Airports Serving Certain Air Carriers.

<u>Environment</u>

The rulemaking team identified and assessed 14 CFR part 34, Fuel Venting and Exhaust Emission Requirements for Turbine Engine Powered Airplanes. The team discussed whether to review ICAO regulations, but decided that ICAO regulations were very similar to 14 CFR part 34. Any conclusions made for 14 CFR part 34 could be used to initiate changes in other regulatory codes, e.g. ICAO, JAR.

3.2 ANALYSES OF THE REGULATORY IMPACT ON EXISTING 14 CFR CODES

3.2.1 General Review Procedures

The rulemaking team assessed each 14 CFR individually.

The team identified the purpose of each CFR part.

It then used engineering judgement and certification experience to conduct an evaluation of each section's regulations considering:

- both ground and on-board inerting system design concepts
- the possibility to introduce inerting systems via retroactive rulemaking (Special Federal Aviation Regulation - SFAR).

The review procedure was refined for each CFR part and is detailed in each subsection below. The procedure refinement was needed in order to ensure the completeness of the evaluation.

3.2.2 Review of 14 CFR Part 21

14 CFR part 21 provides aircraft certification procedures for products and parts.

<u>Review Purpose</u>

The purpose of the rulemaking's team review was to see if any of the current certification procedures would need to be changed if inerting systems were implemented on transport category airplanes.

<u>Review Procedure</u>

The rulemaking team evaluated 14 CFR part 21 considering:

a. Type certification / modification activities

b. Retroactive rule action - SFAR

The group's review basis was as follows:

"For the two certification considerations above, "Do the 14 CFR part 21 regulations permit an inerting system to be certified on a transport category airplane?" If yes, then no changes should be proposed. If no, then state the change.

Because this section concerns procedures, the group decided that the conclusions reached would be equally applicable for ground and on-board inerting systems.

Review Conclusions

a. Type certification / modification activities

   The current regulations are sufficient. No changes are proposed.

b. Retroactive rule action - SFAR

   Any retroactive rule action initiated by the FAA would require a change to 14 CFR part 21, the Special Federal Aviation Regulations (SFAR) section.

   The SFAR regulatory action would need to state the aircraft applicability and the required compliance, including the task accomplishment statement and FAR 25 rule references, the time frame for compliance and the reference to any maintenance or inspection activities.

3.2.3 Review of 14 CFR Part 25

14 CFR part 25 provides airworthiness standards for transport category airplanes; the standards that are used to certify an aircraft, its systems and components.

Review Purpose

The purpose of the rulemaking team's review was to:

- identify which regulations would be part of an inerting system's overall certification compliance plan
- identify if any of the existing regulations need to be modified or if any new regulations need to be created (besides the flammability rule itself) due to the uniqueness of the inerting system's design
- prepare a performance-based flammability regulatory text based on the level of flammability reduction achieved by a practicable inerting system design concept that could be recommended for incorporation into 14 CFR part 25.

Review Procedure

The rulemaking team decided to breakdown this assessment into two parts:

1. the assessment of the regulatory text that require an inerting system to be installed on an aircraft (performance-based flammability regulatory text or *flammability rule*)
2. the assessment of the rules governing the design of the inerting systems (*inerting system rule)*

Part 1 - Implementation of an inerting system via 14 CFR part 25 - Flammability rule

Prior to initiating the FTIHWG, the FAA had proposed via NPRM 99-18 a performance-based flammability regulatory proposal. The Industry made a counter-proposal to the FAA as part of the docket's comments.

The task team decided to use these two proposals as a working basis for any future regulatory text proposals.

Because these two proposals were general in nature and both allowed for an inerting system to be implemented, the team decided to conduct an evaluation of the inerting system itself in order to make sure that all certification issues were understood.

Once the FTIHWG completed its inerting systems' evaluations, then the "implementation" regulatory text (flammability rule) proposals would be revisited.

A comprehensive discussion of how the team assessed the regulatory text that would cause the implementation of an inerting system (performance-based flammability regulatory text) is found in section entitled "Flammability Regulatory Text Evaluation and Proposal".

Part 2 - Inerting system design vs 14 CFR part 25

The impact of the proposed inerting systems on the 14 CFR part 25 code were determined by conducting a certification compliance evaluation of the FTIHWG's ground based and on-board inerting design concepts.

1. Identification of technical considerations

The team first identified the technical considerations that are addressed within 14 CFR part 25. Three technical considerations for the system were identified:

- safety
- design, including installation requirements
- performance

2. Identification of subtopics within the identified technical considerations

These three categories were further subdivided as follows:

   a. Safety
      - Fire protection, explosion proof
      - System safety analysis: FHA, FMEA
      - Overpressure protection for fuel tank / airplane
      - Crashworthiness
      - Venting and drainage protections
      - Ignition source isolation evaluation
      - Physiological effects

   b. Design, including installation requirements
      - Mechanical systems: integrity of components and system integration
      - Electrical systems: integrity of components and system integration
      - NEA distribution capability; assurance that the design maintains an inert condition as declared.
      - Influence of fuel types on the performance of the inert system
      - Structural: structural integrity of components and system integration
      - Retention of the fuel tank's structural integrity (i.e. tank is not over pressurized)
      - Control systems: software and hardware
      - Incorporation of lessons learned, as applicable
      - Line routing flexibility and support, including system layout
      - Effect of rotorburst

- Identification of aircraft flight conditions excluded from the evaluation (example rapid descent)
- Assurance that other fuel system and engine functions and safety features are not significantly affected (i.e. fuel sensor indications, warning and automatic stop features, refuel sequences, tank transfers, …)
- NEA supply specification
- Design objectives; level of redundancy
- Aircraft flammability characteristics within applicant's flight operation envelope and environmental envelope level (needed to substantiate performance considerations).

c. Performance Considerations

- Identification of the system's performance versus flight phase. The systems performance criteria were taken from the tasking statement.
    - For ground based inerting, it was assumed that the system would provide inert gas to the aircraft fuel tank(s) once the airplane reaches the gate, while the aircraft is on the ground between flights and the tanks should remain inert during taxi for takeoff, takeoff, climb and cruise.
    - For on-board ground inerting, it was assumed that the system would provide inert gas to the aircraft fuel tank(s) once the airplane reaches the gate, while the aircraft is on the ground between flights and the tanks should remain inert during taxi for takeoff, takeoff, climb and cruise.

3. Review basis

For each of the subtopics above, the team answered the following questions, once for ground based inerting - component and system level, and once for on-board inerting - component and system level:

a. *WHY* - Identified the certification concern.

b. *APPLICANT ACTION* - Identified the design considerations and acceptable methods of compliance that could be used to address the certification concern (of (a)).

c. *REFERENCE* - Identified the associated 14 CFR part 25 paragraph and identified any areas where the existing paragraphs were insufficient to address the proposed design concepts.

The insufficiencies were recorded and identified as potential 14 CFR part 25 change proposals that are needed in order to accommodate fuel tank inerting systems within the existing regulatory framework.

Review Conclusions

Part 1 - Implementation of an inerting system - Flammability rule

This assessment was conducted separately. The conclusions are found in section entitled "Flammability Regulatory Text Evaluation and Proposal".

Part 2 - Inerting system design vs 14 CFR part 25

The review identified a total of:

- three (3) insufficiencies in 14 CFR 1-1-00 Edition
- thirty six (36) applicable paragraphs in 14 CFR 1-1-00 Edition
- three (3) new concerns unique to inerting systems

Due to the number of considerations that must be regulated within a fuel system inerting design, the team recommends that if inerting systems are to be installed on transport category airplanes, then a dedicated 14 CFR part 25 paragraph, entitled "Fuel Tank Inerting System" should be adopted. This paragraph should be worded in such a way that it can apply to both ground and on board inerting systems. A proposed wording is given below:

Inerting System Regulatory Text Proposal

"§25.xxx Fuel Tank Inerting System

If, in order to show compliance with §25.981(c), a fuel tank inerting system is installed,

(a) the fuel tank inerting system must not, under normal and failure conditions:

  (i) allow any inerting agent leakage into the pressurized or personnel compartments, or confined spaces; and

  (ii) allow overpressure of the fuel system.

(b) The fuel tank inerting system must have:

  (i) A connecting port such that a cross connection with any other supply line is not possible (applicable if supplied by an external inerting gas source).

  (ii) At each inerting agent filler opening and each aircraft opening leading to direct contact with the inert gas, a placard at or near the filler cover or opening with the words "Fuel tank inerting" and the agent denomination.

  (iii) A means to prevent the escape of hazardous quantities of fuel from the system in the case of loss of system supply pressure.

  (iv) A shutoff or isolation means, whose failure to function is evident, that prevents undesirable system functioning and possible fuel leakage.

  (v) A tolerance to variable inerting gas pressures or surges in the gas delivery system.

(c) Cautions (placards) and warnings (indication system) should be provided to prevent unintentional entry into a confined space filled with a hazardous inert gas.

(d) The characteristics and designation of the inert gas that ensure correct operation of the fuel tank inerting system shall be recorded in the operating limitations section of the Aircraft Flight Manual or equivalent."

a. Insufficiencies

  1. Placards

  First insufficiency was found in reviewing the physiological effects of inerting. Because nitrogen enriched air (NEA) is a hazardous substance, the team determined that a placard should be mandated to advise maintenance personnel of the presence of NEA. This mandate can only be enforced via a change to 14 CFR part 25.

The team recommends that the existing 14 CFR §25.1557 - "Miscellaneous markings and placards" - be used to mandate this placard. An additional paragraph (e) "fuel tank inerting systems" can be easily added. This recommendation is applicable to any type of inerting system.

Conclusion:

Add a paragraph (e) to §25.1557 to state that any opening in the aircraft leading to direct contact with NEA should have a placard or be marked with the word "nitrogen" or "NEA" at or near the opening

OR

Create a new fuel system inerting paragraph and include this concern. (see §25.xxx (b)(ii))

2. Ground Based NEA Inerting Filler Connection

Second insufficiency was found when reviewing the ground-based inerting coupling (filler connection). The team determined that the process of filling the tank with NEA could be hazardous if certain design precautions were not taken. For instance, there could be undesirable physiological effects if NEA leaked to other parts of the aircraft or undesirable electrostatic effects if fuel was pumped through NEA distribution system. The list below provides a minimum number of design precautions to be taken. These precautions are similar to those mandated within §25.973 - Fuel Tank Filler Connection.

- Ensure that NEA cannot enter into any part of the aircraft other than the tank itself
- Ensure that the refuel hose connection and the NEA gas hose connection are incapable of cross connection
- Each NEA gas cap must provide a tight seal
- If appropriate (design dependent), provide for electrically bonding the airplane to the NEA inerting ground equipment.

The above design precautions can only be assured if a change to 14 CFR part 25 is initiated.

Therefore, the team recommends that, for ground based inerting systems only, either 14 CFR part 25 §25.973 be amended to include provisions for NEA gas coupling connector or a 14 CFR part 25 paragraph be created to include the above provisions.

Conclusion:

Add a new paragraph to 14 CFR part 25 or amend §25.973 to ensure that the Ground Based NEA Inerting Filler Connection meets the same safety standards as the Fuel Tank Filler Connection and to ensure that the refuel hose and the NEA gas hose cannot be cross connected.

OR

Create a new fuel system inerting paragraph and include this concern. (see §25.xxx (b)(i))

3. Gound Based NEA Inerting - Pressurized system

The third insufficiency was found when reviewing ground based inerting components. NEA is added to the tank via a pressurized ground system. The team therefore determined that the safety precautions for introducing pressurized NEA to the aircraft would be similar to those already mandated for fuel in 14 CFR §25.979 - Pressure Fueling System. Specifically, the team examined four subparagraphs of 25.979: §25.979(a) - addresses the manifold connection, §25.979(b) - addresses the shutoff means, §25.979(c) - addresses prevention of damage to the fuel system in case of shut off valve failure and 25.979(d) - addresses the pressure fueling system structural capability.

Similar to §25.979(a), the team determined that the ground based inerting system should have means to prevent the escape of hazardous quantities of fuel from the system (via backflow) in the case of loss of pressure to the NEA supply.

Similar to §25.979(b), the team determined that a shutoff means/isolation valve is needed to prevent undesirable system functioning and possible fuel leakage. If the applicant chooses to incorporate a mechanical shut-off means/isolation valve, then the failure to close should be evident by design. If a motorized or automatic shutoff means is incorporated then an indication is needed.

Similar to §25.979(c), the team was concerned if failure of the NEA inerting system shut off means could damage the fuel tanks. The design team stated that because it's a constant pressure flow, any failure to close would result in excess NEA being vented out.

Similar to §25.979(d), the NEA inerting system would have to be shown tolerant to variable inerting gas pressures. The safety objective should be similar to the 25.979(d) requirements. However, further research and/or experience on the system may show that other design limits are appropriate.

<u>Conclusion</u>:

For ground based inerting designs only, add a new paragraph to 14 CFR part 25 or amend §25.979 to ensure that the pressurized NEA inerting system:

(a) prevents the escape of hazardous quantities of fuel from the system (via backflow) in the case of loss of pressure to the NEA supply - §25.979(a)

(b) shutoff means/isolation valve is incorporated to prevent undesirable system functioning and possible fuel leakage and that its failure to function is evident - §25.979(b)

(c) not applicable - §25.979(c)

(d) the NEA inerting system should be shown to be tolerant to variable inerting gas pressures or surges in the gas delivery system - §25.979(d)

OR

Create a new fuel system inerting paragraph and include this concern.(see §25.xxx (b)(iii), (b)(iv) and (b)(v)).

b. Applicable paragraphs

The following 14 CFR part 25 paragraphs were found to be pertinent in showing that an inerting system (ground or on-board) is airworthy:

- §25.365 Pressurized compartment loads
- §25.729(f) Wheels and tire failure
- §25.863 Flammable fluid fire protection
- §25.901 Installation
- §25.903 Engines
- §25.954 Fuel system lightning protection
- §25.965 Fuel tank tests
- §25.975 Fuel tank vents and carburetor vapor vents
- §25.981 Fuel tank temperature
- §25.993 Fuel system lines and fittings

- §25.994 Fuel system components
- §25.1181-1207 Powerplant Fire Protection
- §25.1141 Powerplant controls: general
- §25.1301 Function and installation
- §25.1309 Equipment, systems, and installations
- §25.1316 System Lightning Protection
- §25.1353(a) Electrical Equipment and Installations
- §25.1431(c) Electrical Equipment
- §25.1438 Pressurization and pneumatic systems
- §25.1461 Equipment containing high energy rotors
- §25.1529 Instructions for Continued Airworthiness
- §25.1541 Markings and Placards: General
- §25.1581 General Aeroplane Flight Manual section

These paragraphs will be referenced within the guidance material. The utilization and the means to demonstrate compliance to each paragraph are design and applicant specific.

<u>Conclusion</u>

A minimum of thirty six (36) other 14 CFR 25 paragraphs were identified as pertinent to demonstrating the airworthiness of a fuel tank inerting system.

c. New Concerns

Three new issues were raised that are unique to fuel tank inerting systems and that are not found in the current 14 CFR part 25. They are:

- Hazards due to inert gas leakage
- Hazards to the fuel system
- Inert gas characteristics and specification to ensure the system integrity

<u>Hazards due to inert gas leakage</u>

NEA is considered a hazardous substance. NEA is especially hazardous because it cannot be detected by human senses (odorless and colorless) and can cause injury or death within minutes. For this reason any leakage of NEA into the pressurized or personnel compartments or confined spaces requiring maintenance must be avoided and warnings must be incorporated in case of the system's failure to retain NEA. A regulation is therefore needed to ensure that all design and procedural precautions are taken.

<u>Hazards to the fuel system</u>

Inputting inert gas into the fuel system may cause the fuel system to overpressure. This is could lead to a catastrophic failure. A regulation is therefore needed to ensure that all design and procedural precautions are taken.

Inert Gas Characteristics and Specification

The fuel tank inerting system is designed to work with a certain type of inert gas. If another type of inert gas is used, then the system's integrity cannot be ensured. A regulation is therefore needed to ensure that the correct inert gas is used / generated for the certified system.

3.2.4 Review of 14 CFR Part 34

14 CFR part 34 provides fuel venting and exhaust emission requirements for turbine engine powered airplanes.

Review Purpose

The purpose of the rulemaking's team review was to determine if the emissions exhausted from fuel tank vents were regulated and how.

Review Procedure

The rulemaking team reviewed the 14 CFR part 34 paragraphs to determine whether any paragraphs dealt with emissions emitted from fuel tank vent exhausts or from fueling trucks. If a paragraph was found, then it was to be evaluated for change or for reference in any potential guidance material. If no paragraphs were found, then this was to be documented with a possible recommendation for future evaluation.

Review Conclusions

The team found no 14 CFR part 34 paragraphs that regulated the pollution emitted from fuel tank vent exhausts or from fueling trucks. 14 CFR part 34 only regulates the intentional discharge of liquid fuel to the atmosphere that is drained from the nozzle manifold after the aircraft gas turbine engines are shut down.

Some members of the FTIHWG stated that there were state or county laws that forced fuel trucks to recuperate their fumes. The applicability of these regulations was outside the scope of the tasking statement and was not further evaluated.

If inerting is pursued on a large scale and fuel tank vent exhaust emissions are regulated by the U.S. Environmental Protection Agency (EPA) or equivalent, then it is recommended that the appropriate part of 14 CFR (or equivalent) be used as the vehicle to introduce any new aircraft regulatory requirements.

3.2.5 Review of 14 CFR Part 43

14 CFR part 43 provides standards for maintenance, preventive maintenance, rebuilding and alterations.

Review Purpose

The purpose of the review was to determine whether any changes were needed to the 14 CFR part 43 standards due to the uniqueness of an inerting design.

Review Procedure

The rulemaking team reviewed the standards within 14 CFR part 43 to determine if any changes were needed. If a change was identified, then it was recorded. If no changes were identified, then the rulemaking team would issue a recommendation stating that the standards, as written, can accommodate inerting systems.

Review Conclusions

The rulemaking team determined that the 14 CFR part 43 standards did not need to be modified; today's standards can adequately accommodate an inerting system.

3.2.6 Review of 14 CFR Part 121 (Also Applicable to Parts 91/125/129)

14 CFR part 121 provides standards for operating requirements of domestic, flag and supplemental operations.

Review Purpose

The purpose of the rulemaking team's review was to determine the changes required within 14 CFR part 121 in order to accommodate an aircraft operating with a ground based or on-board fuel tank inerting system.

The recommendations from this review can be read over to other 14 CFR parts that provide operating requirements for transport category airplanes.

Review Procedure

The basis for the rulemaking's team review was:

- the design concepts defined by the FTIHWG's ground based and on-board design teams
- the results obtained from the 14 CFR part 25 assessment
- regulatory precedences set by operationally similar systems, e.g. aircraft de-icing

Using the above basis, the assessment of the 14 CFR part 121 standard was conducted.

The assessment results were provided to members of the FTIHWG's maintenance team for further review. The team issued the final recommendations based on the maintenance team's inputs.

Review Conclusions

a. General

The team determined that the type of inerting design and the final decisions by the designers, airlines and operators would highly influence the type of changes needed to 14 CFR operational sections.

The group recognized that issues concerning the reviewed 14 CFR sections may go well beyond the conclusions made below. Under the FAA system, the PIC (pilot in command) is ultimately responsible for the system (i.e. FARs' 121.533, .535, .537), and not the fueler, not the airport management and not the maintenance personnel. This means that the PIC will ultimately be held responsible for:

(a) determining whether the fuel tanks have been properly inerted prior to takeoff, independent of the system (ground or on-board)

(b) determining whether an on-board system can, or cannot, perform its intended function (see FAR 121.563)

(c) deciding what to do in the event of on-board or ground based failures

The PIC's responsibilities as noted in (b) and (c) imply that there must be:

- some cockpit system/indication for determining that the fuel has been inerted to the correct levels in applicable tanks and that it stays that way, i.e. there is no harmful leakage
- abnormal procedures developed based on sensors, cockpit indications and associated caution/ warnings indications

The group also acknowledged that, if inerting systems were embodied, considerations on how to grant MMEL relief, per prescribed FAA procedures, needs to be further studied. The number of potential installations, the complexity of the installations and the method by which the installations are introduced all influence allowed MMEL. Based on the information presented within the ARAC FTIHWG, the rulemaking-team's operational specialists determined that granting of MMEL relief of any inerting system may be complex.

b. All Inerting Systems

Three specific concerns that relate to all inerting systems were identified:

(1) The requirement to have an approved operational and maintenance program

(2) Assurance that NEA (oxygen depleted air) can not physically harm passengers and crew

(3) Statement of when and under what conditions aircraft may need a fuel tank inerting system

Approved operational and maintenance program

The team recommends that the regulatory change be presented in a new 14 CFR 121 (or equivalent) paragraph, in a manner similar to §121.629 - Operation in Icing Conditions. In this way, all of the information can be found in one place and not dispersed between a variety of paragraphs.

The fuel tank inerting paragraph should include the following:

- Statement of the dispatch or release condition of an aircraft containing a fuel tank inerting system
- Requirement for an approved fuel tank inerting program including details:
  - of how the certificate holder determines that he/she needs to inert the aircraft fuel tanks
  - who is responsible for this decision
  - the procedures for implementing this decision
  - the specific duties and responsibilities of each operational position
  - initial and annual recurrent ground training and testing for all personnel affected
- identification of system limitations, e.g. minimum time to inert upon landing or prior to takeoff
- definition of the confined space procedures for the inerting system
- creation of communication procedures
- identification of flight crew's role at dispatch and at landing
- identification of the NEA's specifications/characteristics
- a paragraph that states under what general conditions the more specific requirements are alleviated

This proposed regulatory paragraph should include or reference specific concerns that are only relevant to ground based inerting operations or on-board inerting operations. These specifics are discussed later.

NEA's Physiological effects

Because nitrogen enriched air (oxygen depleted air) can physically harm passengers and crew in confined spaces without adequate ventilation, it is proposed to amend §121.229(c) - Location of fuel tanks - in order to state that NEA gas should be isolated from personnel compartments. The isolation should be shown for NEA gas present in both the fuel tank(s) and the inerting system equipment (pipes, valve, etc.)

The team discussed whether this was not already implicit by stating "fume proof enclosure". It was decided that because no one has ever certified an inerting system on a transport category airplane, and no one has actually analyzed the system's routings and consequences to the aircraft, that it is preferable to that NEA gas should be isolated from personnel compartments.

Conditions under which a fuel tank inerting system is installed

If the FAA decides to mandate fuel tank inerting systems, then the perceived role of this system should be stated within 14 CFR part 121 (or equivalent).

The team recommends creating a new §121.300 paragraph to state when and under what conditions aircraft may need a fuel tank inerting system. This may be accomplishing by a sentence stating that a fuel tank inerting system may be installed on an aircraft as a means to meet the requirements of §25.xxxx of this chapter in effect on a given date.

An alternative recommendation is to modify §121.316 - Fuel tanks, using the same sentence concept.

Conclusion - all inerting systems

A significant amount of changes would have to be made to introduce inerting systems into transport category airplanes day to day operation. The concepts for rule basis changes have been identified. Specifics need to be developed with an appropriate group of experts using a design concept that is proposed for in-service use.

c. Ground Based Inerting System

The team's basis for regulatory changes specific to ground based inerting was established on two facts:

- Ground based inerting is a specific action that requires a specific, independent procedure.
- Ground based inerting cannot be accomplished without the complementary airport facilities

The operational program will be developed using procedures inherent to the ground based inerting design concept.

Because ground based inerting requires interface with the airport and ground personnel (the system is not contained to the aircraft), the team recommends that the new fuel tank regulatory paragraph make references to other applicable paragraphs within 14 CFR. The team proposes that 5 additional 14 CFR 121 paragraphs be modified (or concepts be included within the new fuel tank inerting paragraph):

(1) §121.97 - Airports: Required Data : add NEA supply capability under (b)(1) Airports

(2) §121.105 - Servicing and Maintenance Facilities: include NEA supply capability in equipment example

(3) §121.117 - Airports: Required Data: add NEA supply capability under (b)(1) Airports

(4) §121.123 - Servicing Maintenance Facilities: include NEA supply capability in equipment example

(5) 121.135(b)(8) - Contents - Information Contained in the Manual: add new equipment, (b)(25), concerning inerting facilities or modify (b)(18) to add inerting to the refueling procedures

Conclusion- Ground Based Inerting:

For ground based inerting systems, an additional five other paragraphs need to be created/modified. The concepts of what these paragraphs should contain have been identified. Specific regulatory changes should be reviewed with the operational specialists using a design concept that is proposed for in-service use.

d. On-Board Inerting System

The team's basis for regulatory changes specific to on-board inerting was established considering:

- On-board inerting is a system integral to the aircraft; airport facilities are not needed
- The activation of the on-board system would be done on the aircraft (automatically or manual)

The team did not identify any specific paragraphs for change.

The team determined that the operational program would be developed using procedures inherent to the on-board inerting design concept.

The team identified a potential MMEL impact with on-board inerting that may eventually lead to regulatory changes for pressure vessels. More aircraft everyday are affected by the loss of air from an aging pressure vessel, due to leaks, especially with the classic or aging aircraft. With air being drawn from the pressure vessel for inerting, along with a normal ongoing loss of cabin pressure, the situation exists that it will take the operation of all air conditioning packs to maintain cabin pressure. If this becomes the case, the concern is that operators will lose current MEL relief of operating or dispatching with an inoperative pack in order to assure cabin pressure as well as an operating inerting system.

If an on-board ground system is developed than the ground based and on-board recommendations should both be considered, recognizing that the airport facility requirements would be different (on-board ground - electrical source requirement; ground-based inerting - NEA supply requirement).

<u>Conclusion- On-Board Inerting System</u>:

For on-board inerting systems, no additional paragraphs were identified for creation or modification. If pressure vessel air is used for inerting, regulatory changes may need to be implemented somewhere in the 14 CFR code to ensure cabin air pressure is maintained as the aircraft ages or if it is dispatched on MEL relief with an inoperative pack. On-board ground inerting system may require the regulatory modifications as described under ground based inerting, recognizing that the airport facility requirements would be different (on-board ground - electrical source requirement; ground-based inerting - NEA supply requirement). Specific regulatory changes should be reviewed with the operational specialists using a design concept that is proposed for in-service use.

e. Retroactive rule action

If the FAA decides to initiate any retroactive rule action, it will initiate a change to 14 CFR Part 21 - Certification Procedures for products and parts, Special Federal Aviation Regulations (SFAR) section. The SFAR will state the applicability and the required compliance, including the task accomplishment statement and FAR 25 rule references, the time frame for compliance and the reference to any maintenance or inspection activities.

FAR 121.300 will have to be updated to be in line with the SFAR rule change. The new 121 rule will have to provide provisions concerning time required to introduce the new rule, aircraft effected, operational requirements and any grandfather clauses (especially if there is a time factor linked to equipping domestic and foreign airports).

If the FAA initiates retroactive rulemaking, the team recommends that the appropriate specialists within the Aircraft Evaluation Group work as a team to write the requirements. Specific concern to the rulemaking team is the treatment of an inerting system on MMEL/MEL (master minimum equipment list)/(minimum equipment list) treatment, especially if Airworthiness Directives are issued by the design directorate because §121.628(b)(1) will have to be enforced. §121.628(b)(1) states: “The following instruments and equipment may not be included in the Minimum Equipment List: (1) instruments and equipment that are either specifically or otherwise required by the airworthiness requirements under which the airplane is type certificated and which are essential for safe operations under all operating conditions.”

The group notes that the Aircraft Evaluation Group is responsible for §121.628 - Inoperable Instruments and Equipment - and not the certification and airworthiness branch.

Conclusion - retroactive rule

A retroactive rule would be initiated by FAA decision and by a simultaneous change to 14 CFR part 21 and 14 CFR part 121 (or equivalent). The retroactive rule needs to be closely coordinated within both the FAA's certification / airworthiness standard branch and the Aircraft Evaluation Group. The FAA needs to consider carefully any retroactive rule action versus its impact on the MMEL/MEL.

f. Impact on 14 CFR part 121 (or equivalent) Subpart L, N and T

The team examined the impact of introducing a fuel tank inerting system on Subpart L - Maintenance, Preventive Maintenance and Alterations, Subpart N - Training Program and Subpart T - Flight Operations.

Given the amount of knowledge that the team has on the inerting systems and their impact on aircraft operations, the team does not recommend any specific changes to Subpart L, N or T.

However, the team recognizes that there will be a need for specific training on the embodied inerting system. This training may have to be regulated within 14 CFR part 121 (or equivalent). The regulatory text would be in line with the system's complexity. For instance, specific requirements may be instituted to ensure that a person is adequately trained for ground based servicing of an aircraft with NEA, especially if the aircraft is being serviced from gas bottles, so that the wrong gas is not put into the tanks, e.g. oxygen inputted instead of NEA.

Conclusion - Impact on 14 CFR part 121 (or equivalent) Subparts L, N and T

There are no recommendations for modifications to Subparts L, N and T based on today's knowledge of the systems. The current wording is sufficient in order to ensure proper training on inerting systems. Modifications or new paragraphs may need to be introduced once an inerting system is actually proposed for in-service use.

3.2.7 Review of 14 CFR Part 139

14 CFR part 139 provides standards for certification and operations of land airports serving certain air carriers.

Review Purpose

The purpose of the review was to determine whether any changes were needed to the 14 CFR part 139 standards due to the airport services needed to support an inerting design.

Review Procedure

The rulemaking team reviewed the standards within 14 CFR part 139 to determine if any changes were needed. If a change was identified, then it was recorded. If no changes were identified, then the rulemaking team would issue a recommendation stating that the standards, as written, can accommodate inerting systems.

Review Conclusions

The team's review identified one change to 14 CFR part 139 standards, if ground based inerting is implemented. No changes to 14 CFR part 139 were identified if on board inerting is implemented.

The change identified concerns §139.321 paragraph(b) - Handling and Storing of Hazardous Substances and Materials. Paragraph (b) states that

"Each certificate holder shall establish and maintain standards acceptable to the Administrator for protecting against fire and explosions in storing, dispensing, and otherwise handling fuel, lubricants, and oxygen (other than articles and materials that are, or are intended to be, aircraft cargo) on the airport.

These standards shall cover facilities, procedures, and personnel training and shall address at least the following:

(1) Grounding and bonding.

(2) Public protection.

(3) Control of access to storage areas.

(4) Fire safety in fuel farm and storage areas.

(5) Fire safety in mobile fuelers, fueling pits, and fueling cabinets.

(6) After January 1, 1989, training of fueling personnel in fire safety in accordance with paragraph (e) of this section.

(7) The fire code of the public body having jurisdiction over the airport."

If one considers NEA as the hazardous substance, then §139.321 should be modified to add a paragraph that regulates the handling of NEA. This regulation should discuss fire safety issues, as well as confined space entry and handling issues.

If one considers that hazardous substance is the flammable vapor in the aircraft fuel tanks, and that these flammable vapors are generated by the flow of fuel from a fueling operator into the tank, then an item (b)(8) can be created. Item (b)(8)'s purpose would be to ensure the airport controls the hazard presented by an aircraft fuel tank with flammable vapors. If this option is chosen, then the airport would need to ensure:

a. A supply of NEA inert gas, in sufficient quantities, is available in order to fuel tank ullage wash all commercially operated aircraft serving the certified airport.

b. facilities, procedures and personnel training standards in place to protect against in-tank explosion of flammable vapors of fuel tanks on commercially operated aircraft parked upon the premises of the certified airport.

c. all commercially operated aircraft departing the certified airport has been provide the opportunity to have its fuel tank ullage washed with inert NEA gas within "x" hours of its next departure from the certified airport.

<u>Conclusion</u>

If ground based inerting is pursued and the airport facilities are responsible for providing the NEA inert gas to the airport, then a revision to 14 CFR 139 is needed.

The revision can be justified in one of two ways. The first way is to regulate the safety of the public and airport when handling NEA. The second way is to regulate the hazard of the airplane and state that the airport must ensure that this hazard doesn't exist.

The revised regulatory text should address:

- availability of NEA gas
- facility, procedures and personnel training standards
- infrastructure to ensure aircraft are inerted within a minimum time before its next departure

More specific wording was not developed because of the immaturity and impracticality of ground-based inerting.

3.3 DEVELOPMENT OF GUIDANCE MATERIAL FOR FUEL TANK INERTING SYSTEMS

Upon completion of the fuel tank inerting regulatory assessment, the rulemaking team began its development of guidance material for use in designing, certifying and operating a fuel tank inerting system.

As with the regulatory evaluation, both ground based and on-board systems were considered within the development of the guidance material.

This section provides:

- the methodology used to develop the guidance material
- elements of the proposed guidance material
    - design/certifications
    - operation
- recommendations for future work

3.3.1 Methodology Used to Develop the Inerting System Guidance Material

The regulatory text change review identified four core subjects:

1. Retroactive rule - SFAR (14 CFR parts 21 and 121)
2. Design and certification (14 CFR parts 25 and 34)
3. Operation and maintenance (14 CFR parts 43, 91, 121, 125 and 129)
4. Airport Facilities (14 CFR part 139)

The rulemaking team opted to develop guidance material for two of the four subjects:

- Design and certification (14 CFR parts 25 and 34)
- Operation and maintenance (14 CFR parts 43, 91, 121, 125 and 129)

The team determined that the retroactive rule did not need associated guidance material by nature and that the FTIHWG's airport facilities team was addressing the airport facilities issues.

The team was split by expertise. The design specialists drafted the design and certification guidance material. The operational specialists drafted the operation and maintenance guidance material.

Both teams drafted the guidance material assuming that the decision had already been made to fit a fuel tank inerting system (ground or on-board) on the aircraft. (See section entitled "Flammability Regulatory Text Evaluation and Proposal" for guidance material associated to the flammability regulatory text - how to evaluate the aircraft to decide if an inerting system needs to be fitted.)

3.3.2 Guidance Material - Design and Certification of a Fuel Tank Inerting System

This section describes the objective and proposed content of guidance material associated to the design and certification of a fuel tank inerting system. The complete guidance material proposal is found in Attachment 1 of this report.

The guidance material was derived using the fuel tank inerting systems design proposals of the two FTIHWG design teams and the regulatory evaluation assessment.

The team recommends that this guidance material be refined using real fuel tank inerting design concepts that are proposed for in-service aircraft.

3.3.2.1 Objective
The objective of the team was to develop guidance material that provides information and guidance on the design, installation and certification of a NEA inerting system.

This material could then be used, if desired, to create an Advisory Circular pertaining to fuel tank inerting systems.

3.3.2.2 Assumptions
The team assumed that the applicant chose to install a NEA inerting system on one or all of its aircraft's fuel tanks. The design objective of the system is to reduce or eliminate the flammable environment created in the fuel tank's fuel/air vapor ullage (means by which to show compliance to FAR/JAR 25.xxx).

The team assumed that this guidance material would be harmonized between the US Federal Aviation Administration (FAA) and Joint Aviation Authority (JAA) prior to its publication.

The team took for granted that this guidance material would not become mandatory and would not constitute a regulation. It's purpose is to provide the applicant with advice and a method of compliance that has been found acceptable to the FAA / JAA (certifying Authorities).

3.3.2.3 Background
The team determined that if the guidance material is transformed into a stand-alone advisory circular, then a background section should be included as part of the advisory circular. If the guidance material is included in an existing advisory circular then the background section should be reviewed and updated as appropriate.

The team proposed a background section in its guidance material proposal, Attachment 1. This section states the conditions under which the guidance material proposal was drafted. The contents of this section may become obsolete as the subject matures.

3.3.2.4 Related Documents
The team then went on to list all the documents that were known to its members and that were relevant to this fuel tank inerting design and certifications.

Five categories of documents were identified:

a. Related 14 CFR part 25 and part 34 paragraphs

b. Published or draft FAA Advisory Circulars

c. Society of Automotive Engineers (SAE) documents

d. Military specifications

e. Other publications

The purpose of the document list is to assist designers in finding supplementary information.

If this guidance material is transformed into an advisory circular, the team recommends that this listing be double checked in order to make sure that this list is not obsolete.

3.3.2.5 Definitions and Abbreviations
The team recorded all definitions and abbreviations that it felt were pertinent to a fuel-tank inerting system designer and certificator.

Some of the definitions proposed within this guidance material are supplementary to or different from those proposed by the FAA in AC 25.981-2.

3.3.2.6 Inerting System Design Concepts

The team decided that the guidance material should explain the general concept of fuel tank inerting and then explain the fundamental principles behind different fuel-tank inerting design concepts. The material developed by the FTIHWG design teams was used as the basis for the design concept explanations.

The purpose of the general concept section is to explain what is fuel tank inerting and what is its effect on the fuel/air vapor environment within the fuel tank.

The purpose of the different fuel-tank inerting design-concept sections was to identify the:

1. general principles of the inerting design
2. flight phases for which the design is most likely effective
3. general impact on the aircraft design and the aircraft operation (system criteria / operational impact, including airport facilities interface)
4. specific concerning unique equipment, e.g. air separator module (ASM)

3.3.2.7 System Installation Considerations

Fuel tanks become inert because of the operation of a system - the fuel tank inerting system.

The guidance material identifies some of the inerting system's installation considerations.

Specifically, the guidance material discusses design of the

- Distribution system
- Vent system
- Indications

3.3.2.8 Aircraft Interfaces

The fuel tank inerting system needs to be integrated with the other aircraft systems and needs to comply with all relevant 14 CFR part 25 paragraphs.

Review of the FTIHWG's identified, the following aircraft systems that may need to interface with a fuel tank inerting design:

- Electrical
- Engine bleed air
- Cabin pressurization
- Refuel

The guidance material provides installation considerations that are specific to inerting systems.

3.3.2.9 Certification Plan / Compliance Demonstration

This section of the guidance material provides general certification guidance by providing suggestion on what should be included within the fuel-tank inerting's certification plan.

The guidance material suggests that the certification plan should include:

a. A description of the fuel-tank's inerting design and operation

b. A definition of the safety assessment activities and its inter-relationship with other activities within the design approval process

c. An analysis that demonstrates the system's effectiveness and operating characteristics

d. A test program definition where the test program is defined as ground, flight and/or laboratory testing.

The certification plan should be submitted by the applicant and approved by the Authority. The complexity of the certification plan will depend on the newness of the inerting's design, the newness of the aircraft installation and the experience of the applicant in designing and certifying.

3.3.2.10 Continued Airworthiness / Maintenance Considerations

The applicant will need to define the fuel-tank inerting's continued airworthiness requirements and an associated maintenance program.

The guidance material recommends that established industry procedures are used.

The team notes, however, that this section may need to be enhanced once an actual system evaluation is performed.

3.3.2.11 Nitrogen Enriched Air (NEA): Precautions to Respect

Nitrogen Enriched Air is a hazardous substance. Design precautions should be taken to avoid that any person comes in contact with NEA. Various studies have shown that improper handling of NEA or entry into a confined space without precautions can be deadly.

The guidance material states the above. The guidance material also suggests that the designer become familiar with OSHA confined space requirements. In this way the design and associated maintenance procedures can ensure that all possible precautions be built into the system to prevent bodily harm and death.

3.3.2.12 Environmental Impact

The FTIHWG determined that there would be some additional hydrocarbons spewed from the fuel tank due to inerting. The quantity was not determined. The quantity would also depend on the type of inerting system installed.

The team also determined that 14 CFR part 34 does not regulate fuel tank emissions.

However, the team was not sure if particular airports or foreign airports had different emission considerations.

The purpose of this guidance material section is to alert the designer that:

- NEA inerting displaces VOCs (increases the amount of hydrocarbons put into the atmosphere)
- Possible airport restrictions may require additional vapor recuperation techniques

3.3.2.13 Master Minimum Equipment List (MMEL) Assessment

The FTIHWG recommends that a fuel tank inerting system be considered for dispatch under the MMEL.

The guidance material makes this recommendation. It also states that the MMEL should be determined using standard industry procedures.

3.3.2.14 Final Recommendations

The guidance material developed complements that already published in AC 25.981-2. AC 25.981-2 describes the general concept of an inerting system, where as this proposal not only discusses the general concept but specific design considerations.

If the FAA decides to encourage inerting system installations on aircraft, the team recommends that either AC 25.981-2 be expanded to include fuel-tank inerting design considerations or a specific AC entitled "Fuel Tank Inerting Design and Certification" be created.

It is recommended that any Advisory Circular be re-reviewed using an actual certified inerting design. The design considerations recommended in this guidance material are based on hypothetical designs. The lessons learned during an actual design project may assist others in designing and certifying aircraft.

3.3.3 Guidance Material—Operation and Maintenance of a Fuel Tank Inerting System

This section describes the objective and proposed content of guidance material associated to the operation and maintenance of a fuel tank inerting system and to the receipt of an approved fuel tank inerting program. The complete guidance material proposal is found in Attachment 2 of this Appendix.

The guidance material was derived using the fuel tank inerting systems design proposals of the two FTIHWG design teams, the regulatory evaluation assessment and guidance material written on systems that interface with airport facilities or systems that are implemented because of environmental concerns.

The team recommends that this guidance material be refined using real fuel tank inerting design concepts that are proposed for in-service aircraft.

3.3.3.1 Objective

The objective of the team was to develop guidance material that provides:

- information and guidance on the operation and maintenance of a NEA inerting system
- guidance in obtaining approval of a fuel tank inerting program

This material could then be used, if desired, to create an Advisory Circular pertaining to fuel tank inerting systems.

3.3.3.2 Assumptions

The team assumed that the aircraft had a fuel tank inerting system (ground or on-board) installed and that the applicant (AC user) is an operator seeking to gain approval of its fuel tank inerting maintenance and operation program

The team assumed that this guidance material would be harmonized between the US Federal Aviation Administration (FAA) and Joint Aviation Authority (JAA) prior to its publication.

The team took for granted that this guidance material would not become mandatory and would not constitute a regulation. It's purpose is to provide the applicant with advice and a method of compliance that has been found acceptable to the FAA / JAA (certifying Authorities).

3.3.3.3 Background

The team determined that if the guidance material is transformed into a stand-alone advisory circular, then a background section should be included as part of the advisory circular. The information contained in this section should be similar to the information contained in the design and certification design advisory material, with any specific information being included for relevant to operations and maintenance.

The guidance material, in Attachment 2, proposes a background section.

3.3.3.4 Related Documents

The team then went on to list all the documents that were known to its members and that were relevant to this subject.

This list should be similar to the list produced for the design and certification advisory material. Any specific maintenance or operational documents, that do not influence design changes, should be quoted.

If this guidance material is transformed into an advisory circular, the team recommends that this listing be double checked in order to make sure that this list is not obsolete.

3.3.3.5 Definitions and Abbreviations

The team recorded all definitions and abbreviations that it felt were pertinent to the operation and maintenance of a fuel-tank inerting system. The definition list should be similar to the list included in the design and certification guidance material.

3.3.3.6 Fuel Tank Inerting Program Parts

The team determined that any fuel tank inerting operation and maintenance program would contain six parts:

1. Management plan
2. Dispatch conditions, including any timetables
3. Operations Manual - Inerting operational procedures
4. Maintenance program - maintenance manual
5. Training
6. Health and Safety Standards

Note: Emissions: Local airport emission requirements may have to be evaluated against the possible excess of fuel tank emissions resulting from inerting. (Emissions effects will be design and aircraft dependent.)

3.3.3.7 Management Plan

A management plan is a detailed description of the operational responsibilities and procedures associated with the implementation and conduct of the certificate holder’s “fuel tank inerting program”. The management plan may differ depending on the type of inerting system.

The purpose of the management plan is to ensure operational control (ensure proper execution of a fuel tank inerting program).

The management plan needs to be submitted and approved by the FAA. It should include:

- the name of the manager responsible for the overall fuel tank inerting program,
- this manager’s organization including the individual group (task) managers, their functions and responsibilities against each applicable 14 CFR
- the specific elements covered by the plan. The elements should either be detailed within a specific document or be cross referenced to other internal documents

Specific elements for which the management organization needs to be detailed and approved are:

a. operations
b. maintenance

c. aircraft servicing on ground

d. others deemed critical to the management and operation of the fuel-tank inerting system

3.3.3.8 Dispatch Conditions, Including Any Timetables

Certain design features - aircraft (e.g. fuel tank's vent system) or fuel tank inerting system - may impose certain utilization conditions or limitations. These conditions / limitations may be related to time, outside ambient temperatures, flight phase, fuel tank loading or a set of multiple conditions.

If a limitation exists, then the certificate holder's program should define operational responsibilities and should develop procedures to instruct the flight crew, aircraft dispatchers, flight followers, and maintenance and ground personnel on the condition limitations, evaluation of these limitations and the resultant action to take. The procedures should include gate procedures, communication procedures with the ground and flight crew and coordination with ATC (air traffic control)

The limitations should be supported by the manufacturer's design data.

3.3.3.9 Operations Manual—Inerting Operational Procedures

Operational procedures associated to the fuel tank inerting system installed on the aircraft type should be approved as part of an operator's initial operational manual approval or as a revision to that manual, the Airport Handling Manual and/or the Minimum Equipment List.

Procedures most likely needing changing are flight preparation procedures and ground handling instructions.

A quality assurance program should be put into place in accordance with the management plan and applicable 14 CFR regulations.

The MEL should be developed based on the manufacturer's recommendations and the operator's operational policies and national operational requirements.

3.3.3.10 Maintenance Program—Maintenance Manual

Maintenance procedures for the fuel tank inerting system installed on the aircraft type should be approved as part of an operator's initial maintenance manual approval or as a revision to that manual.

Special emphasis should be put on the development and implementation of all procedures and precautions implemented because of inerting and in particular - handling of NEA, e.g,. fuel tank purge procedures (open and confined spaces), fuel tank entry procedures and NEA handling policies.

For ground based inerting, the characteristics / specification of the NEA that will be used to inert the fuel tanks should be defined and recorded in the appropriate manuals.

For on-board inerting, particular attention should be paid to the efficiency (service life) of the air separator module (NEA producing capability), noting that NEA will not be produced if this component does not perform its intended function.

3.3.3.11 Training

Initial and recurrent ground training and testing for all affected personnel (e.g. aircraft dispatchers, ground crews, contract personnel, flight crew, etc.) need to be put in place.

The training syllabi should be adapted to each discipline and to the type of inerting system installed on the aircraft. For maintenance personnel, specific attention should be placed on the dangers of NEA and precautions to take when working in confined spaces.

A quality assurance program should be put into place in accordance with the management plan and applicable 14 CFR regulations.

3.3.3.12 Health and Safety Standards

The operator's health and safety standards should be updated to include working with NEA. Specific areas may include but are not limited to:

- NEA handling
- Emergency care procedures
- Working in confined spaces
- Identification of health risks
- Identification of protective clothing

3.3.3.13 Emissions

Local airport emission requirements may have to be evaluated against the possible excess of fuel tank emissions resulting from inerting. (Emissions effects will be design and aircraft dependent.)

If the evaluation indicates there is a necessity to recover the VOCs, then procedures would have to be adopted accordingly and recorded within the management plan and the manual. Training courses would also need to incorporate these differences within the affected disciplines' course.

3.3.3.14 Final Recommendations

The guidance material developed within the FTIHWG describes the steps needed to obtain approval of a fuel tank inerting Operation and Maintenance Program. There is no other known recommended guidance material or Advisory Circulars existing in the public domain.

If the FAA decides to encourage inerting system installations on aircraft, the team recommends that this guidance material be used to issue an Advisory Circular entitled "Fuel Tank Inerting Operational Program Approval".

It is recommended that any Advisory Circular be re-reviewed using an actual operation and maintenance program developed for use on a certified fuel tank inerting system. The lessons learned during the implementation of the operation and maintenance program may assist others in any future implementation exercise.

3.4 FLAMMABILITY REGULATORY TEXT EVALUATION AND PROPOSAL

The rulemaking team was tasked to develop a regulatory text that could be used to regulate the fuel tank ullage environment. The FAA requested the team to develop a performance-based text where the performance criterion was defined as flammability.

The FAA's tasking statement set down the following ground rules by which the team was strictly bound:

- for the proposed regulatory text, fuel-tank inerting could be an acceptable method of compliance
- flammability was to be treated independently from fuel tank ignition prevention
- "performance-based" definition provides the applicant with a set of design requirements, not a prescriptive design requirement
- "flammability" definition - the susceptibility of the fuel/air vapor (ullage) present in a fuel tank to igniting readily or to exploding
- flammability reduction only through fuel tank inerting was to be considered by the FTIHWG, which was asked not to address or consider other methods for controlling the flammability of fuel tank ullage

3.4.1 Methodology Used to Develop the Flammability Regulatory Text Recommendation

In order to provide and substantiate a regulatory text recommendation, the team:

- identified the key parameters that could lead to controlling the fuel tank ullage environment
- identified the perceived regulatory expectations
- defined how the regulatory text may be associated to aircraft safety objectives
- proposed an outline for an evaluation standard that could be used to ensure an equivalent safety level across all product lines, including percent exposure

Regulatory text proposals were developed and evaluated (pros and cons) using the results of the above investigation.

3.4.2 Parameters That Lead to Controlling Fuel Tank Ullage Environment

The key parameters that could lead to controlling the fuel tank ullage environment were identified. This list served as the regulatory text word source. That is, in order to meet the tasking-statement's objective, the regulatory text had to be written using a variation of this word list or "parameters". The following list of "parameters" was identified:

- Flammability
- Flammable vapors
- Vapors
- Oxygen content
- Ullage
- Inerting
- Environment
- exposure

- Minimization
- Development
- practical
- Limit
- control
- Ignition energy
- Temperature
- Center wing tank
- Heated center wing tank
- Body tank / auxiliary (“aux”) tanks / aircraft center tank (ACT)
- Wing tanks
- Trim tank / horizontal stabilizer tank
- Flight phase: ground operation (gate), taxi to take-off, take-off, climb, cruise, descent, landing, taxi into the gate

3.4.3 Regulatory Text Expectation

The team agreed that the primary purpose of the flammability regulatory text was to reduce the risk of a fuel tank explosion by reducing or eliminating the flammable environment that exists in the fuel tank’s ullage space.

It was agreed that flammable environment did not pose a hazard to the aircraft in isolation. The hazard was posed only if an ignition source with sufficient energy came in contact with an ullage environment that could support combustion (fuel is in its flammable range and the oxygen content is high enough to support combustion). If one or both of the items contributing to the hazardous situation were removed then fire/explosion of the fuel tank would not occur.

Recalling the task team’s ground rules for regulatory text development, the team determined that the regulatory text should:

- Equate “flammable environment control” to demonstrating that the ullage environment can not support combustion if it comes in contact with a spark.
- Ensure that the applicant controls the environment either by demonstrating that the:
    - fuel is not in the flammable range (varies with temperature, fuel type and altitude), or
    - oxygen content is too low to support combustion

The acceptable design or procedural methods and substantiation that achieve the regulatory text’s expectations are left up to the applicant.

The effectiveness and conditions under which the design/procedures need to function/be enforced should be dictated by the aircraft’s design and overall safety features.

3.4.4 Regulatory Text as Associated to Aircraft Safety Objectives

The team agreed that the regulation of fuel tank flammability could be a contributing element in preventing the aircraft “fuel tank explosion”. This conclusion was based on the circumstantial evidence and the lack of specific cause findings in the recent fuel tank explosion accidents (see the safety section of the FTIHWG's report).

The team discussed what level of safety (per 14 CFR part 25, §25.1309) and hence redundancy should the system be required to have. This question remained unanswerable.

The tasking statement did not allow the team to examine the system as a whole versus the aircraft event "fuel tank explosion". This type of assessment would have backed out the flammability system's safety level and redundancy level because the applicant would have determined when the other features on the aircraft left the aircraft at risk. The residual risk (when and how much) would have determined the type and safety level of flammability reduction measures.

The tasking statement required that the flammability regulatory text to be independent of the other aircraft-design features. This situation did not allow other features of the aircraft to be used to set the safety and redundancy level for the system. The tasking statement provided guidance on safety level (safety enhancement) and redundancy (none). However, some group members stated that the tasking statement's assumptions were not realistic. In a "real-world" certification exercise, the applicant would either be forced to identify the "risk" condition and eliminate it or if the "risk condition" could not be identified, to design a system that ensures a flammability exposure as close to zero as possible. Both the severe design objectives and the aircraft operational reliability objectives would back out the system redundancy. In fact, most group members agreed that the system would have to be redundant to become feasible for a day-to-day transport category airplane use.

Within this discussion the team determined that any flammability regulation should ensure the "risk" condition, as defined by the accident statistics, should be assessed and found acceptable. This "risk" condition, called from now on, the "accident risk condition", was identified to be:

- aircraft operating under hot day conditions
- center wing tank empty with heat being inputted
- ground or climb phase

The group also agreed that due to uncertainty of how the accidents occurred, the "accident risk condition" should not be considered as the only risk condition. Any regulatory text and associated guidance material should ensure that similar or new-risk conditions are not created in other fuel tanks besides the center tank.

For instance an evaluation of the other tanks should be undertaken, when the fuel tank is empty or the primary potential ignition sources are uncovered (e.g. pumps). This evaluation should determine whether the fuel tank ullage enters the flammable zone and under what conditions. The design could then be altered to ensure that the risk is mitigated.

3.4.5 Regulatory Text Proposals

Regulatory text proposals were developed based on discussions of the previous section and FTIHWG Terms of Reference guidelines. Each regulatory text proposal was recorded. Pros and cons of each proposal were evaluated against the conditions discussed. A representative sample of regulatory text proposals is given below. The team used these options along with the work from the other FTIHWG groups to make a final regulatory proposal to the HWG.

<u>Option A</u>

Section 25.981 (c) Flammable Fuel Vapors

Limit the development of flammable conditions in the fuel tanks, based on the intended fuel types, to less than X% of the expected fleet operational time defined in appendix X,

or

Provide means to m itigate the effects of an ignition of fuel vapors within the fuel tanks such that any damage caused by an ignition will not prevent continued safe flight and landing

<u>Pros</u>:

- provides choices on how to control the fuel tank ullage environment
- words “limit” and “development” are performance based terms that can be interpreted within the preamble and guidance material
- an Appendix can be used to standardize the evaluation criteria
- provides an alternative means of compliance - control of aircraft structural integrity and not control of the fire triangle provided through the “or” option
- allows for a compliance interpretation so that all fuel tanks need to be studied

<u>Cons</u>:

- because the X% is based on the overall average fleet operational time, the specific risk areas as defined by the accident statistics may be overlooked
- the results may vary due to a choice of mission parameters; mission parameters chosen may not resemble the actual operation of the aircraft
- due to variations in aircraft designs and missions, the derivation of a common industry standard X% may prove to be difficult
- the same design precautions may be able to be achieved by looking at a specific type of operation and not a fleet average

<u>Option B</u>

Section 25.981 (c) Center Wing Tank Ullage Environment

(i) under ground conditions, assess the center wing tank’s thermal characteristics to show that the development of flammable conditions is limited (or an alternative wording with the same intent - limit the development of flammable ullage)

(ii) provide means to mitigate the effects of an ignition of fuel vapors within the fuel tanks such that any damage caused by an ignition will not prevent continued safe flight and landing.

<u>Pros</u>:

- specifies the condition which is the major contributor to the risk “ground conditions”
- words “limit” and “development” are performance based terms that can be interpreted within the preamble and guidance material

- specifies the type of evaluation that needs to be done in order to take a design decision on how to manage fire triangle
- provides an alternative means of compliance - control of aircraft structural integrity and not control of the fire triangle provided through the "or" option
- states that an evaluation needs to be performed
- design objective is inherent and is not subjected to an interpretive percent value

Cons:

- does not require all fuel tanks to be assessed; too restrictive per tasking statement
- does not require an examination of the thermal characteristics under all flight phases to examine the state of the ullage environment
- The acceptable standard for "limiting" may change with time; an acceptable approach and design may not be acceptable for a future product due to a change of philosophy by an individual certificating authority

> *Option C*
>
> Section 25.981 Fuel tank ignition prevention
>
> (c) If systems adjacent to fuel tanks could cause significant heat transfer to the tanks:
>
> (i) Means to reduce heating of fuel tanks by adjacent systems shall be provided; or...
>
> (ii) Equivalent flammability reduction means shall be provided to offset flammability increases that would otherwise result from heating; or...
>
> (iii) Means to mitigate the effects of an ignition of fuel vapors within fuel tanks shall be provided such that no damage caused by an ignition will prevent continued safe flight and landing.

Pros:

- Provides multiple options of controlling the environment and states that any one of the options are equally acceptable
- Is responsive to the issue of temperature's effect on fuel tank ullage flammability
- Precludes the use of design methods that result in a relatively high likelihood that flammable vapors will develop in fuel tanks
- Provides a measurable design objective - flammability level in a heated tank shall be near that of an unheated tank
- "means to reduce heat" and "equivalent flammability reduction" can be described in guidance material

Cons:

- Does not meet the tasking statement because it is too specific in terms of the role of temperature within the evaluation

<u>Option D</u>

Section 25.981 Fuel tank ignition prevention

(c) If ignition sources can develop in the fuel tanks, then

(i) evaluate the fuel tank ullage flammability to determine whether any type or group of tanks have flammability characteristics significantly different than the others

(ii) if different, then provide justification to show:

(a) that all practical precautions have been taken to equate the tank or tanks to within 5°C (10+°F) of the slowest cooling tank on the aircraft , or

(b) that the fuel tank ullage environment is made non-flammable (inert), or

(c) means to mitigate the effects of an ignition of fuel vapors within fuel tanks shall be provided such that no damage caused by an ignition will prevent continued safe flight and landing.

<u>Pros</u>:

- states that if a tank does not have any ignition sources in the tank then the environment does not have to be considered
- requires an evaluation of all fuel tanks
- provides a performance comparison basis (tanks of the same aircraft)
- provides a flammability performance target via the cool down rate (temperature) or suppression of the flammable environment (inert)
- Implicates the notion that body tanks should be similar to wing tanks understanding that there is a physical difference between the two tank concepts

<u>Cons</u>:

- Does not meet the tasking statement because it speaks about the role of ignition sources within the environmental analysis assessment
- May not be practical to apply to in-service aircraft
- Temperature delta may not be considered prescriptive

<u>Option E - FAR Amendment 25-102</u>

Section 25.981(c) The fuel tank installation must include:

(1) Means to minimize the development of flammable vapors in the fuel tanks (in the context of this rule, “minimize” means to incorporate practicable design methods to reduce the likelihood of flammable vapors), or

(2) Means to mitigate the effects of ignition of fuel vapors within fuel tanks such that no damage caused by an ignition

<u>Pros</u>:

- Word “minimize” and “development” are performance based term that can be interpreted within the preamble and guidance material
- provides an alternative means of compliance - control of aircraft structural integrity and not control of the fire triangle provided through the “or” option
- design objective is inherent and is not subjected to an interpretive percent value

- implies that all fuel tanks and all flight/ground conditions are implicated in the evaluation
- Provides multiple options of controlling the environment and states that any one of the options are equally acceptable
- States the meaning of minimize with the rule text

Cons:

- a specific Appendix imposing an evaluation method is not proposed in the regulatory text
- it is up to the applicant to show "minimization"; the guidance material and preamble will provide guidance on how to "minimize"
- "minimize" does not provide a measurable goal. It is up to the applicant and regulating authority to determine that the design is satisfactory. This may lead to inconsistent level of safety.
- The acceptable standard for minimization may change with time; an acceptable approach and design may not be acceptable for a future product due to a change of philosophy by an individual certificating authority

3.4.6 Conclusion

After much deliberation, the team decided that the existing regulatory text introduced by FAR Amendment 25-102 best met the requirement of the tasking statement (Option E).

Inerting systems could be evaluated against the word practicable. That is, if the inerting system were found to be practicable then it would become the minimum standard; if not practicable then some other means of flammable reduction would become the minimum standard.

The team decided to discard the other options because it was:

Option A: impractical to impose a numerical limitation due to the lack of an industry agreed pass/fail criteria.

Option B: flight phase limiting; "risk" may occur in a flight phase other than ground

Option C: primary means of compliance is through heat control; this is too restrictive for inerting and the tasking statement

Option D: linked to ignition source control and therefore outside of the tasking statement; impractical to impose a numerical limitation due to the lack of an industry agreed pass/fail criteria

3.4.7 Guidance Material Associated to the Regulatory Text

The rulemaking team agreed that the flammability regulatory text should be associated to some guidance material.

The purpose of the guidance material is to define the "standard" by which the applicant's product is going to be evaluated and judged acceptable. It should be used to identify the design and/or procedures that are needed to ensure the safety of the aircraft design. The guidance material should not identify how to design a system. For example, the guidance material associated to this rule should not provide advice to an applicant on how to design and operate a fuel tank inerting system.

The "standard" should be subdivided into four subtopics:

1. The circumstances for conducting an assessment of flammability
2. Decision to pursue regulatory text evaluation

3. Assessment of the flammability - the state under which the product needs to be placed in order to obtain the parameters needed to make a judgement on performance (similar to the playing field and the rules of the game.)
4. The standard itself - the basis on which the compliance decision will be based (determination of compliance)

The team agreed that an acceptable performance based rule is one in which the regulatory text and the standard are compatible and ensure an equivalent safety level across all product lines.

<u>Development of the "standard" limited by the tasking statement</u>

The tasking statement limited the team's ability to develop a flammability "standard".

The tasking statement required the team to determine whether fuel tank inerting could be used as the practicable industry standard to show compliance to a flammability regulatory text. The FAA considered that Subtopics 1-3 were addressed by its Advisory Circular AC 25.981-2. Therefore, the rulemaking team only addressed subtopic 4.

<u>Development of a "standard" excluding the tasking statement instructions</u>

Some team members felt if the FTIHWG was to endorse or create a flammability regulatory text, then all subtopics within the "standard" definition should be addressed irrespective of the tasking statement.

The team decided to discuss each subtopic and document its general concerns. These concerns could then be expanded as appropriate to the regulatory text development.

<u>*Circumstances For Conducting An Assessment Of Flammability*</u>

AC 25.981-2 provides guidance in this area.

However, some team members felt that a flammability rule should not be applied to fuel tank ullage if all of the mechanical and electrical potential ignition sources were removed.

This determination could be made by developing qualitative pass/fail criteria; no credit is given for probability of failure. The design either complies with the condition "pass" or does not comply with the condition "fail".

If the applicant passes the checklist then the flammability regulatory text is not applicable.

<u>*Decision to pursue regulatory text evaluation*</u>

The team agreed that the purpose of the flammability regulatory text needed to be clearly stated within the guidance material.

The aircraft design goal (aircraft safety objective) needs to be stated. Any performance-based words - "minimized", "limit", etc. - need to be defined. The definition can be specified as a specific goal (X% flammability exposure) or by a design assessment associated to a pass/fail criterion.

Some team members felt that the guidance material should give credit for mitigation of ignition sources via one of two means:

1. Protection of the tank from structural and systems damage in case that ignition of fuel/vapor air mixture took.

   An example of an acceptable means is the use of appropriate foam. The fuel tank is filled with a type of foam that ensures the control of the pressure rise following an ignition of the fuel/air vapor mixture.
2. Snubbing of the spark prior to its coming in contact with the flammable fuel/air vapor mixture (an ignition is not created).

<u>*Assessment of the flammability*</u>

AC 25.981-2 provides a method to determine the average flammability exposure of a given tank.

Some team members raised concerns over whether an average flammability exposure calculation really provides the correct type of assessment needed to prevent the "accident risk".

It was estimated that at least seven parameters needed to be assessed to determine if the "accident risk" has been mitigated. They are:

1. *Influence of outside ambient air temperature* - ISA / ISA +23°C (73.4°F) variation can be used to determine operational limitations and measure the effectiveness of any design/operational changes based on outside conditions.
2. *Effect of fuel loading on the fuel tank heat transfer characteristics* - the results can be used to show the thermodynamic influence of fuel on the overall ullage cooling behavior and resultant flammability exposure.
3. *Thermodynamic characteristics of each equipment/system* - the results can be used to identify the contribution of each equipment/system to the overall ullage characteristics. This in turn can be used to identify design changes or operational constraints (master minimum equipment list, ground operation procedures).
4. *Influence of ground operation time* - the results can be used to understand the influence of ground operation on the fuel tank ullage temperature. The results can be used to substantiate design decisions or operational procedures.
5. *Identification of hot spots* - the results can identify whether there is a local change in the flammability characteristics of the ullage.
6. *Differences/similarities between the tanks* - the results can identify whether any tank has an unusual thermodynamic characteristic as compared to the others. This reason for this difference can be evaluated and the used to determine if any design or operational actions need to be taken.
7. *Identification of the magnitude that a design is influenced by natural physical properties versus by design choices* - the results can be used to establish a comparison basis with ambient conditions. The results from the unheated configuration show the flammability exposure characteristic of the design based only on fuel loading, pressure and aerodynamic effects. The results from the heated configuration show the influence of the internal fuel system mechanical components and the adjacent systems on the flammability exposure. The comparison of heated and unheated results can be used to show the direct benefit on flammability exposure of any design or operational changes under a certain fuel loading and outside ambient air condition.

Team members agreed that probably both the average risk and specific risk were needed to ensure that all hazards were addressed within the design.

<u>*Determination of compliance*</u>

Team members voiced concerns over the utilization of the interpretative words such as "minimize" or "limit the development".

Experience on past projects have shown that differing opinions between the applicant and Authority of what constitutes "minimize" or "limit" has led to costly delays in some certification programs.

Industry team members encouraged the FAA and JAA to work with them as an industry group, to develop a process and associated numerical conditions by which applicable can be judged. An example of a process, is a flow chart that provides acceptable design conditions and choices on how to proceed depending on conditions. An example of a numerical condition is an average flammability exposure percentage or a temperature limit.

3.5 CERTIFICATION COST ASSESSMENT

Below are list of activities required for certification of a fuel tank inerting means. This estimate is for one model aircraft and is not specific to a Ground Base or On-Board fuel tank inerting system. This estimate does not include design and installation of the system.

a. Qualification Testing (Assumed 4 New Parts) – 1,440 Hours Total

1) Review & Approve Qualification Test Procedures/Plans for New Parts (1 Man – One Month per plan)

   Approximate Hours = 1 * 160 * 4 = 640 hours (includes conformity request)

2) Witness Testing (1 Man - One Month)

   Approximate Hours = 160 hours

3) Review and Approve Qualification Test Reports (1 Man - One Month per report)

   Approximate Hours = 1 * 160 * 4 = 640 hours

b. Lab Development/Testing – 6,500 Hours Total

1) We need to make sure we can distribute the gas throughout the tank and that the individual components function as a system. This requires planning, coordination, tank design & fabrication, system check out, test conduct, documentation and facility restoration.

   Approximate Labor Hours = 6,100 hours
   Approximate Material Cost = $ 40,000 = 40,000/100 = 400 hours

Airplane Testing - 16,049 Hours Total

2) Write Engineering Work Authorization (1 Man - Two Week)

   Approximate Hours = 1 * 40 * 2 = 80 hours

3) Write/Review Detailed Ground Test Plans and Flight Test Tip Sheets (3 Man – One Month)

   Approximate Hours = 3 * 160 = 480 hours

4) Conformity Inspection/Instrumentation/Shop Support/Flight Test Support (based on 737-NG FAA test)

   Approximate Hours = 13,765 hours

5) Ground Test Portion (Ground Crew 3, Test Engineers 2, System Engineers 2, FAA Representative 1, Airplane Ground Test Hours of 68 based on 737-NG FAA test)

   Approximate Hours = (3 + 2 + 2 + 1) * 68 = 544 hours

   a) Demonstrate Fuel Tank Inerting Procedures
   b) Ensure tank remains inert during prolonged ground operations with X-Wind

6) Flight Test Portion (Flight Crew 2, Ground Crew 3, Test Engineers 2, System Engineers 2, FAA Representative 1, Airplane Flight Test hours of 54 based on 737-NG FAA test)

Approximate Hours = (2 + 3 + 2 + 2 + 1) * 54 = 540 hours

a) Demonstrate that Fuel Tank (s) remain inert during applicable phases of flight (taxi, takeoff, climb, cruise) with different fuel loads.

7) Propulsion Laboratory/Flight Test Reports (2 Man - Two Months)

Approximate Hours = 2 * 160 * 2 = 640 hours

c. Certification Documents – 2880 Hours Total

1) Prepare and submit a Certification Plan (1 Man Month)

Approximate Hours = 1 * 160 = 160 hours

2) System Description & Analysis Report Including the System Safety Assessment (Two Man – Three Months)

Approximate Hours = 2 * 160 * 3 = 960 hours

3) Ground & Flight Test Reports (2 Man - Three Months)

Approximate Hours = 2 * 160 * 3 = 960 hours

4) FAA coordination (1 Man Month)

Approximate Hours = 1 * 160 = 160 hours

5) Support Flight Operations Evaluations Board & MSG-3 Analysis (I Man Month)

Approximate Hours = 1 * 160 = 160 hours

6) Engine Rotor Burst Analysis Applicable only to the On-Board Inerting System (3 Man Months)

Approximate Hours = 3 * 160 = 480 hours

Sum Total = 26,869 hours (approximately 6 Man – Two Years)

ATTACHMENT 1
GUIDANCE MATERIAL -
FUEL TANK INERTING SYSTEM - DESIGN, INSTALLATION AND CERTIFICATION

1. Purpose

The intent of this section is to tell the reader what is in this guidance material and how it can be used. An example of how this section could read is provided below:

"This advisory material provides information and guidance on the design, installation and certification of a NEA inerting system.

An applicant may choose to install a NEA inerting system within one or all of its aircraft's fuel tanks in order to reduce or eliminate the flammable environment created by the fuel tank's fuel/air vapor ullage (means by which to shown compliance to FAR/JAR 25.xxx).

The guidance provided within this advisory material is harmonized with the US Federal Aviation Administration (FAA) and Joint Aviation Authority (JAA) and is intended to provide a method of compliance that has been found acceptable. As with all AC material, it is not mandatory and does not constitute a regulation."

2. Background

This section should include background material that is compatible with both the Advisory Circular that it's published in and the regulation that it's supporting. The background material drafted below provides the circumstances under which this guidance material was drafted. It is recommended that this section be revised upon publication of any of this material.

"Following the TWA 800 accident, both the NTSB and the FAA, questioned whether reducing or eliminating the flammable fuel tank environment could improve aircraft safety by further reducing the risk of a fuel tank explosion.

Traditionally, fuel tank explosions are prevented, by ensuring that there are no ignition sources within the flammable fuel-tank environment. Since the TWA 800 accident, the emphasis on fuel-tank ignition source prevention has increased. Both in-service and new type certificated aircraft have improved the robustness of their fuel-tank ignition source prevention designs. The FAA has issued a change to the FARs (FAR Amendments 21-78, 25-102, 91-266, 121-282, 125-36 and 129-30) in order to ensure that fuel-tank ignition sources are prevented.

However, even with the increased robustness of fuel-tank ignition source prevention, the FAA has concluded that a safety benefit may be achieved if the applicants took precautions to minimize the fuel/air flammable environment (termed the "flammable vapors") on future airplanes.

The FAA, therefore, proposed a change to FAR 25 via NPRM 99-18 (published in Amendment 25-102) to add a requirement, §25.981(c), such that

"The fuel tank installation must include:

(1) Means to minimize the development of flammable vapors in the fuel tanks (in the context of this rule, "minimize means to incorporate practicable design methods to reduce the likelihood of flammable vapors), *or*

(2) Means to mitigate the effects of an ignition of fuel vapors within fuel tanks such that any damage caused by an ignition will not prevent continued safe flight and landing."

The FAA has also published an associated guidance material (AC No. 25.981-2, entitled "Fuel Tank Flammability Minimization") to complement FAR §25.981(c). The FAA stated that the purpose of this AC is to provide "information and guidance concerning compliance with the airworthiness standards for transport category airplanes pertaining to minimizing the formation or mitigation hazards from flammable fuel air mixtures within fuel tanks".

Fuel tank inerting is suggested in Section 7.(a) of the AC as a means to reduce the flammable environment within a fuel tank. In fact, section 7.(a) states that "Fuel tank inerting is a highly effective means of reducing or eliminating the flammability exposure within a given fuel tank."

When a FAA sponsored study (FAA Report DOT/FAA/AR-00/19) that fuel tank inerting was not only an efficient but economically viable solution, the FAA formed the ARAC Fuel Tank Inerting Harmonization Working Group. One of this group's tasks was to formulate guidance material that could be used in designing an inerting system.

The guidance material presented herewith is the result of this task group. Its purpose is to provide a comprehensive guide on the considerations that an applicant should give to developing, installing and certificating a NEA inerting system.

3. Related Documents

Related Federal Aviation Regulations. (FAR Sections (limited to FAR 25))

An initial review of the 14 CFR part 25 sections shows that the following paragraphs prescribe the design requirements for the substantiation and certification of a NEA inerting system as presented within the ARAC FTIHWG. This should be reviewed prior to the publication of any Advisory Material.

1) Paragraph that directly leads to fuel tank inerting

§25.981(c)	Flammability minimization

2) new paragraph:

§25.xxx	Fuel Tank Inerting System
others, if created	

3) applicable paragraphs to fuel systems, installation, indications

§25.365	Pressurized compartment loads
§25.729(f)	Wheels and tire failure
§25.863	Flammable fluid fire protection
§25.901	Installation
§25.903	Engines
§25.954	Fuel system lightning protection
§25.965	Fuel tank tests
§25.975	Fuel tank vents and carburetor vapor vents
§25.981	Fuel tank temperature
§25.993	Fuel system lines and fittings
§25.994	Fuel system components
§25.1181-1207	Powerplant Fire Protection
§25.1141	Powerplant controls: general
§25.1301	Function and installation
§25.1309	Equipment, systems, and installations
§25.1316	System Lightning Protection
§25.1353(a)	Electrical Equipment and Installations
§25.1431(c)	Electrical Equipment
§25.1438	Pressurization and pneumatic systems
§25.1461	Equipment containing high energy rotors
§25.1529	Instructions for Continued Airworthiness
§25.1541	Markings and Placards: General
§25.1581	General Aeroplane Flight Manual section

Advisory Material

An initial review of existing FAA advisory circulars identified a number of Advisory Circulars that that may be of assistance to the applicant when designing, substantiating and certification an inerting system as presented within the ARAC FTIHWG. This list would need to be updated at the time of publication of any Advisory Circular.

1) Existing Advisory Circulars or other standards

AC 25-8	Auxiliary Fuel System Installations, dated 5/2/86
AC 25-53A	Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Due to Lightning, dated 4/12/85
AC 25.981-1B	Fuel Tank Ignition Sources Prevention Guidelines, dated 4/18/01
AC 25.981-2	Fuel Tank Flammability Minimization, dated 4/18/01

2) Other Guidance Material Under Development within the FTIHWG

   Guidance material - Operation and Maintenance of a Fuel Tank Inerting

<u>Society of Automotive Engineers (SAE) Documents</u>

The following documents published by the Society of Automotive Engineers may be useful when designing, substantiating and certificating a fuel tank inerting system as presented within the ARAC FTIHWG. This list would need to be updated at the time of publication of any Advisory Circular.

1) SAE AIR 5128 "Electrical Bonding of Aircraft Fuel System Plumbing Systems," (January 1997).
2) SAE AIR 4170, "Reticulated Polyurethane Safety Foam Explosion Suppressant Material for Fuel Systems and Dry Bays"
3) SAE AIR 1903 "Aircraft Inerting Systems." (Draft)
4) SAE AIR 1662, "Minimization of Electrostatic Hazards in Aircraft Fuel Systems," (October 1984).

<u>Military Specifications</u>

The military specification reference is came from AC 25.981-2. No other published information from the military was made available to the ARAC FTIHWG. An enhanced research may be performed at the time of publication of a draft Advisory Circular.

1) MIL-B-83054, Baffle and Inerting Material, Aircraft Fuel Tank (March 1984)

<u>Other</u>

Some other publications were identified as being useful when designing, substantiating and certificating an inerting system as presented within the ARAC FTIHWG. An enhanced research may be performed at the time of publication of a draft Advisory Circular.

This list may need to be expanded, as more information becomes published:

1) FAA Document DOT/FAA/AR-98/26, Review of the Flammability Hazard of Jet A Fuel Vapor in Civil Transport Aircraft Fuel Tanks, June 1998. (A copy of this report can be obtained through the National Technical Information Service (NTIS), Springfield, Virginia 22161, or at the following web site address: http://www.fire.tc.faa.gov)
2) Aviation Rulemaking Advisory Committee, Fuel Tank Harmonization Working Group, Final Report, July 1998 (a copy of this report may be obtained on line from the U.S. Department of Transportation (DOT) electronic dockets, Docket No. FAA-1998-4183, at the following web site address: http://dms.dot.gov)

3) "Effects of Fuel Slosh and Vibration on the Flammability Hazards of Hydrocarbon Turbine Fuels Within Aircraft Fuel Tanks," Technical report AFAPL-TR-70-65 (November 1970), Edwin E. Ott. (Contact Airforce Aero Propulsion Laboratory, Airforce Systems Command, Wright-Patterson Air Force Base Ohio.)

4) FAA Order 8110.34A, "Procedures for the Use of Fuels for Turbine Powered Aircraft,", March 1980.

5) FAA Document DOT/FAA/AR-99/65, "Mass Loading Effect on Fuel Vapor Concentrations in Aircraft Fuel Tank Ullage"

6) FAA Document DOT/FAA/AR-00/19, "The Cost of Implementing Ground Based Fuel Tank Inerting in the Commercial Fleet", May 2000

7) Aviation Rulemaking Advisory Committee, Fuel Tank Inerting Harmonization Working Group, Final Report

8) OSHA Standard Number 1910.146 - Permit-required confined spaces subpart J, General Environmental Controls

4. Definitions / Abbreviations

The definitions and abbreviations listed hereunder are those that may be pertinent to the design and certification of a fuel tank inerting system. Some of the definitions are different than those appearing in AC 25.981-1 and/or -2 and are marked as such.

a) ASM: Air separator module - either a passive permeable membrane system that relies on polymer membranes to separate nitrogen from air or a molecular sieve system that adsorbs oxygen from the air

b) Center wing tank: A fuel tank located in the aircraft's wing box but located within the fuselage of the aircraft.

c) Flammable: Flammable, with respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding. (14 CFR Part 1, Definitions).

d) Flammability exposure: "Exposure" refers to the mission time where a combination of items in a fire triangle, required to obtain combustion, exists. The fire triangle consists of oxygen, flammable fuel, and an ignition source. If any one of these is removed, combustion will not occur.

   Note: Because fuel flammability varies with fuel temperature, fuel type and fuel altitude, exposure may vary based on the heat transfer characteristics of a fuel tank. For instance, any fuel tank that presents a large surface area to the airstream could have a smaller exposure than a fuel tank within the fuselage.

e) Flammability range: The pressure (i.e., altitude)/temperature domain where the fuel vapor/air mixture is flammable. This domain is dependent on the type of fuel used.

f) Fuel air ratio (FAR): The ratio of the weight of fuel vapor to the weight of air in the ullage.

g) Fuel scrubbing: Use of inerting gas to dilute the dissolved oxygen in the fuel.

   Fuel scrubbing involves the injection of inert gas in a stream of fuel. The fuel is divided in multiple small streams which provides a large fuel surface area. The inert gas is mixed with these streams and absorbed by the fuel surface. This dilutes the oxygen concentration of the air already in the fuel.

   To remain inert, the fuel must be placed in a tank with inert ullage. (Otherwise, it will absorb oxygen and give up nitrogen.)

   Once the fuel is scrubbed and the aircraft enters its climb and early portion of the cruise flight phase, the inert gas (mostly nitrogen) will evolve out of the fuel to the ullage.

h) Fuel tank: An aircraft volume containing fuel. Tanks contain both liquid fuel and, in the vapor space or ullage space, a fuel vapor/air mixture, with some water vapor, depending on the relative humidity in the tank.

i) Fuel types: Different fuels are approved for use in turbine powered airplanes. The most widely used fuel types are JET-A/JET-A1 and JET-B (JP-4), per ASTM Specification D1655-99, "Standard Specification for Aviation Turbine Fuels." The approved fuel types for a given airplane type are listed in the Airplane Flight Manual (AFM). Each fuel type has its own properties; those directly related to flammability are "flash point" and "distillation" characteristics. Property differences can occur in a given fuel type as a result of variations in the source crude oil properties and the refining process used to produce the fuel.

j) Heated fuel tank: Fuel tanks that experience a rapid rise in temperature due to the adjacent system equipment.

k) Inert fuel tank: Fuel tank inerting, as applied to aircraft fuel tanks, can be defined as the inclusion of a gas, in the ullage prior to ignition of the vapor, that will suppress that ignition, independent of the fuel air mixture.

l) Inert gas: A gas that will not oxidize. In fuel tanks, the ullage in considered inert when the O2 concentration is approximately 10% or less (unless future data shows otherwise), when nitrogen is used as the inert gas.

m) Lean Fuel Vapor/Air Mixture: A fuel vapor mixture that has insufficient concentration of fuel molecules below that which will support combustion.

n) NEA: Nitrogen enriched air - a gas with nitrogen purity of 90-98%.

o) Operational time: The time from the start of preparing the airplane for flight, (turning on the auxiliary power unit (APU) /ground power, starting the environmental control systems etc.,), through the actual flight and landing, and through the time to disembark any payload, passengers and crew.

p) Rich Fuel Vapor/Air Mixture: A fuel vapor/air mixture that contains a concentration of fuel molecules above that which will support combustion

q) Ullage or ullage space: The volume within the tank not occupied by liquid fuel.

r) Ullage washing: Use of inert gas to dilute the air above the fuel (ullage).

s) Unheated fuel tank: a fuel tank that is not heated

(AC 25.981-2 definition - A conventional aluminum structure, integral tank of a subsonic transport wing, with minimum heat input from the aircraft systems or other fuel tanks that are heated.)

t) Wing tank: A fuel tank located within the aircraft's wing.

Note: Generally, any tank that presents a large surface area to the airstream could be considered to have the same exposure as a wing tank. For example, fuel tanks in the horizontal or vertical stabilizer, wing-mounted pods, or externally-mounted fuselage or fairing tanks.

5. Inerting System Design Concepts

Various NEA inerting system design concepts exist. Each proposed system design concept may provide a different level of flammability protection to the aircraft.

The intent of this proposed section is to provide the applicant with general information regarding the different concepts of NEA inerting systems and general level of flammability protection that can be expected from each concept.

The applicant can then use this information to assess, which, if any, NEA inerting system could be pursued for its aircraft application.

a.) General fuel tank inerting concept

This section explains what fuel tank inerting is and its effect on the fuel/air vapor environment within the fuel tank.

Fuel tank inerting, as applied to aircraft fuel tanks, can be defined as the inclusion of a gas in the ullage prior to ignition of the vapor that will suppress that ignition, independent of the fuel air mixture. The gas used can be one that simply reduces the oxygen available for combustion, such as NEA, or one that chemically interferes with the combustion process, such as Halon 1301.

This advisory material discusses only inerting systems using NEA. Therefore, the fuel tank inerting definition can be simplified to read “fuel tank inerting is the process of displacing air from the fuel tank with an inert gas (NEA) in order to decrease the probability of combustion”.

Military studies (SAE document 1903, “Aircraft Inerting Systems”) show that the oxygen content of the fuel tank ullage should be less than 9% in order to prevent fuel tank combustion after tank penetration by a high-energy incendiary (HEI) round.

For commercial applications, minimum oxygen concentration needed to prevent catastrophic fuel tank rupture may vary by tank design. Studies indicate that a 10% by volume oxygen concentration level is sufficient to prevent combustion and subsequent catastrophic consequences, in the unlikely event of an ignition source in the fuel tank.

Further research is ongoing to evaluate the effect on commercial aircraft fuel tanks, if the minimum oxygen concentration level is increased. These results may be used as a basis for new design criteria when available.

b.) Ground Based Inerting

The purpose of this section is to state:

(1) the general principles of ground based inerting

(2) flight phases for which ground based inerting is effective

(3) the general impact on the aircraft design and the aircraft operation (system criteria / operational impact, including airport facilities interface)

b.1) General principles of ground based inerting

A ground based inerting system ensures ullage washing using a source of inerting gas at the airport (external to the aircraft) and a dedicated aircraft NEA distribution system.

The NEA is supplied to the fuel tanks, by an external ground source, via a dedicated line connected to the aircraft at a specific connector. The ground connection point is a type, which only allows connection to the appropriate ground equipment. It should be positioned as to minimize interference with baggage handling and other ground departure activities.

The NEA is distributed to the fuel tanks via an aircraft distribution system. The pipe that goes between the connection and the fuel tank wall should be doubled walled in order to ensure that a single failure does not release NEA into the pressurized area or an enclosed space. The manifold installed in the tank contains a series of outlets/nozzles that discharge the NEA. Initial testing done by the FAA on a B737, showed that the volume required to inert the tank ullage is approximately 1.7 times the maximum ullage space.

The ground source supply should be controlled to ensure that the delivered pressure does not exceed the allowable value for the aircraft type being serviced. The maximum supply pressure required to avoid exceeding tank design limits differ for each aircraft design.

The typical time to inert a large transport category aircraft is estimated to be around 20 minutes.

b.2) Flight phase for which ground based inerting is effective

The effectiveness of ground based inerting depends on the outside ambient air temperature, the amount of fuel in the tank(s), the aircraft vent system and the fuel type.

FAA sponsored testing on a B737, showed that ground based inerting may be effective during the ground, taxi, takeoff, climb and a portion of the cruise flight phase (with the possibility of retaining the effectiveness until the top of descent).

b.3) General impact on the aircraft design and the aircraft operation

Ground based inerting system has an effect on the aircraft design, the airport facilities needed to dispatch the aircraft and the aircraft departure procedures. Ground based inerting may have an effect on the aircraft turnaround time.

The advantages of a ground based inerting system are:

- there is a minimal impact on the aircraft weight,
- system complexity limited; system is relatively simple
- aircraft system interfaces are minimized
- standard approach to supply every aircraft with a set volume of NEA (1.7 times the maximum ullage volume) can be used
- direct aircraft cost and certification cost are minimized

The disadvantage of this system is :

- complexity and cost linked to the airport facilities and infrastructure
- recurring labor costs to provide the NEA to the aircraft
- limited protection during climb and some of cruise (depends on initial fuel load)
- only inerts center wing tank..

The overall system's operational complexity will vary depending on the amount of system automatism. For example, a non-complex system's operation could consist of:

- connecting the ground supply to the aircraft
- selecting the isolation valve open
- adding an appropriate volume of NEA
- closing the isolation valve
- disconnecting the NEA supply
- filling in a control sheet to indicate that the operation has been carried out and to record the amount of NEA added. The sheet will be passed to the flight crew for confirmation that the correct quantity was loaded.

The amount of equipment added to the aircraft will again depend on the system's complexity and the number of tanks to be inerted. Some specific design features to consider are listed hereunder:

- ensure that there is no damage to the aircraft in the event of the aircraft moving while the ground equipment is still connected: consider inclusion of a self sealing coupling incorporating a frangible device
- detect for fuel leakage into the pipe: consider installing a witness drain
- isolate the tank from an external pipe: consider installing an isolation valve

– prevent backflow of the fuel in the event of loss of pressure in the NEA supply: consider incorporating a non-return valve
– relieve any pressure that may build up in the pipe due to temperature changes: consider installing a thermal relief valve
– indication of the isolation valve functioning: consider installation of a control switch and caption lamp
– ensure that a single failure does not release NEA into the pressurized area or an enclosed space: consider double walled pipes between the connection to the tanks

Note: The ground connection coupling used in this design should be associated to an industry standard. This industry standard needs to be developed if GBI is pursued.

Other issues that need to be considered are:

– need for dedicated ground personnel
– impact on overall ground servicing operations
– impact on the airport; infrastructure, equipment, etc.
– potential environmental issues from venting the tanks overboard

c.) On Board Ground Based Inerting (OBGI), including hybrid system

The purpose of this section is to state:

(1) the general principles of on-board ground based inerting

(2) flight phases for which on-board ground based inerting is effective

(3) the general impact on the aircraft design and the aircraft operation (system criteria / operational impact, including airport facilities interface)

(4) Air separator module

c.1) General principles of on-board ground based inerting

An on-board ground based inerting system ensures ullage washing, on the ground only, via a system that carries all equipment necessary to inert the fuel tanks on board the aircraft.

This system does not operate in-flight. This system assumes that the selected fuel tanks are inert prior to leaving the terminal gate.

NEA is produced by equipment located on the aircraft. This NEA is then fed into an aircraft distribution system similar to the GBI system.

NEA is produced by forcing air through an ASM. The air must be conditioned prior to entering the ASM - temperature / water content / purity.

The system's operational objectives, amount of NEA to be produced and delivered to the aircraft's fuel system, must be assessed for each aircraft design. For instance, assumptions such as the minimum turn around time to get the tanks inert, the air source (outside or APU), the gate operational restrictions for the APU need to be considered prior to undertaking the design.

As with GBI, the system should be designed to ensure its compatibility with the fuel tank pressure limits.

The estimated time to inert a large transport category aircraft is 60 minutes.

A hybrid OBGI system can be designed. A hybrid OBGI would only run during taxi-in and taxi-out. It provide less protections than a sized OBGI system, but would reduce the system's weight, volume, power and air consumption.

c.2) Flight phase for which on-board ground based inerting is effective

The effectiveness of on-board ground based inerting depends on the outside ambient air temperature, the amount of fuel in the tank(s), the aircraft vent system, the fuel type and the capacity and operating time of the system.

The effectiveness of this system is similar to that of ground based inerting (see b.(2)).

c.3) General impact on the aircraft design and the aircraft operation

On-board ground based inerting system has an effect on the aircraft design, the airport facilities needed to dispatch the aircraft and the aircraft departure procedures. On-board ground based inerting may have an effect on the aircraft turnaround time.

The advantages of an on-board ground based inerting system are:

- it can use airport resources such as air carts or electrical carts for power
- there is no operational impact between this system and other aircraft systems;
- certification activities are simplified compared to an on-board in-flight system
- aircraft is self sufficient; it is a better solution for remote airports

The disadvantages of an on-board ground based inerting system are:

- the size and the weight of the system
- the cost linked to the airport facilities (less than for ground based inerting)
- hull/skin penetration necessary for the compressor's ram air inlet and exhaust, as well as for the heat exchangers
- affect on engine/aircraft performance
- increased electrical power usage at the gate; requires a dedicated power source
- compressor and cooling fan noise
- increase in maintenance exclusion zones on ground
- provides limited protection during climb and some of cruise (depending on initial fuel load)
- poor reliability

The overall system's operational complexity will vary depending on the amount of system automatism. For example, a typical OBGI system, that is not redundant, not cross-vented, has no warm up times for the ASMs and does not affect turn around time, could consist of:

- providing air to the system via an electrically driving air compressor (or alternative bleed air source)
- conditioning the air to enter into the ASMs - temperature, water content, purity
- producing the nitrogen via an ASM
- controlling the O2 content
- distributing the NEA to the aircraft fuel tanks
- the operational control of the system, start and shutoff of the system, could be performed semi-automatically
- a recording system to state that the NEA has been added to the aircraft fuel tanks should be envisaged

The amount of equipment added to the aircraft will again depend on the system's complexity and the number of tanks to be inerted. Some specific design features to consider are listed hereunder:

<u>compressor</u>:

- containment features or location chosen so as to mitigate the effects of uncontained rotating equipment failure
- thermal cut-out features or ice / FOD prevention features to prevent motor overheat

– spark or flame arrestors incorporated in the compressor inlet and exits to avoid generation and propagation of sparks

ducts / vents:

– external temperature elements to automatically shutoff the system when an overheat is detected
– double walled ducting to limit the chance of NEA leakage into the pressurized section of the aircraft
– ventilation to avoid built up of NEA
– oxygen rich vents located away from fuel sources so as to not create a fire hazard
– bonding the tubing of the distribution system to prevent the creation of static electricity at high velocity flow rates of NEA

valves / sensors:

– pressure relief system to avoid fuel tank overpressure
– temperature monitoring sensors to avoid hot air being pumped into fuel tanks and increasing the risk of fuel tank explosion

general:

– development of confined entry space procedures
– air monitoring system (O2 level)
– system to ensure hot gas is not input into the tanks
– features to prevent icing of components, especially the ASM or water separator/filter
– indication system providing information on how system is operating

Other issues that need to be considered are:

– air inlet and exhaust for compressor and heat exchangers require hull/skin penetration
– potential risk from oxygen by-product
– appropriate space on the aircraft needed to fit the equipment
– potential environmental issues from venting the tanks overboard

c.4) Air separator module

The air separator module is a line replaceable unit and should be easily accessible by maintenance personnel.

The choice of ASM is up to the system designer.

One choice may be a passive permeable membrane system that relies on polymer membranes to separate nitrogen from air.

A second choice may be a molecular sieve system that adsorbs oxygen from the air.

Considerations that should be taken within the design choice are:

– Durability
– Sensitivity to hydrocarbon contamination
– Sensitivity to water contamination

d.) On-Board Inert Gas Generating System (OBIGGS) including Hybrid System

The purpose of this section is to state:

(1) the general principles of on-board inert gas generating system

(2) flight phases for which on-board inert gas generating system is effective

(3) the general impact on the aircraft design and the aircraft operation (system criteria / operational impact, including airport facilities interface)

(4) Air separator module

d.1) General principles of on-board inert gas generating system

An on-board inert gas generating system, OBIGGS, generates and distributes inert gas to selected fuel tanks at all times during the flight.

The OBIGGS design definition should be compatible with the system operational objectives (flammability exposure level).

<u>Full time operation</u>: This type of OBIGGS system is recommended for applicants that want to stay inert throughout the flight envelope. The system design is generally driven by the aircraft descent and descent rate because the system tries to produce enough inert gas to equalize the fuel tanks and to prevent ambient air from entering the fuel tank. This type of design keeps the system inert at all times.

<u>Hybrid system - Intermittent or low-flow operation</u>: This type of OBIGGS system is recommended when some small exposure time is permitted and when the system size is a concern. The system selectively applies inerting to certain tanks during a specific portion of the aircraft profile. For example, this system would typically not need to be sized for descent due to the minimal exposure time of the descent (compared to the takeoff , climb and cruise) or because the fuel and ullage in the tank may have cooled off during flight.

The distribution of the NEA is via an aircraft distribution system, similar to that both the GBI and OBGI system.

The NEA is produced by forcing conditioned (temperature / water content / purity) air through an ASM. The air source is the aircraft - either aircraft cabin air or bleed air.

OBIGGS is not operated on the ground so it has no effect on turn around time. OBIGGS is not operated on the ground because it is continuously topping up the tanks.

As with all inerting systems, the OBIGGS system should be designed to ensure its compatibility with the fuel tank pressure limits. For OBIGGS, if cabin air is used as the source, particular attention needs to be paid to the aircraft pressurization requirements.

d.2) Flight phase for which on-board ground based inerting is effective

A full time OBIGGS system is effective during all flight phases.

A hybrid system (an intermittent or low flow system) is effective during a selected number of flight phases. The system designer chooses these flight phases.

d.3) General impact on the aircraft design and the aircraft operation

OBIGGS has an affect on the entire aircraft design. It does not have an affect on the aircraft turn around time because it is continually topping up the tanks throughout the flight.

OBIGGS is sized to inert during normal ground and typical flight operations. Normal operations include normal takeoff, climb, cruise, descent, landing and ground operations. Emergency descent is not a normal operation. The driving case for the design is normal descent.

The advantages of an OBIGGS system are:

– All fuel tanks are inerted through all phases of flight
– Aircraft is self sufficient; it can be used at all airports
– Reduced corrosion and condensation in the fuel tanks

The disadvantages of an OBIGGS system are:

- The size and weight of the system
- Engine / aircraft performance are affected
- Hull/skin penetration necessary for the compressor's ram air inlet and exhaust, as well as for heat exchangers
- Drag penalties from heat exchanger ram inlet, exit and ASM waste exit
- Potential interference with cabin re-pressurization during descent
- If air is drawn from the cabin, cabin air distribution patterns may be affected
- Compressor and cooling fan noise
- Decreased thrust recovery from the outflow valve
- High pressure ratio compressor

The overall system's operational complexity will vary depending on the amount of system automatism. For example, a typical OBIGGS system, that is not redundant, not cross-vented, does not effect turn around time, uses bleed air as its source during climb and cruise and cabin air as its source during descent, and is not operated between flights could consist of :

- Providing air to the system via the aircraft cabin or bleed air source via an electrically driven compressor (6:1 for large and medium transport, 4:1 for all others)
- Conditioning the air to enter the ASM - temperature, water content, purity
- Producing NEA via an ASM
- Controlling the O2 content and pressure prior to NEA entering the fuel tanks
- Distributing the NEA to the aircraft fuel tanks
- The operational control of the system, start and shutoff of the system, could be performed automatically with a manual override in case of system failure
- A method to ensure that NEA is being added to the aircraft fuel tanks should be envisaged

The amount of equipment added to the aircraft will depend on the system's complexity and the number of tanks to be inerted. Some specific design features to consider are listed here under:

<u>compressor</u>:

- containment features or location chosen so as to mitigate the effects of uncontained rotating equipment failure
- thermal cut-out features or ice / FOD prevention features to prevent motor overheat
- spark or flame arrestors incorporated in the compressor inlet and exits to avoid generation and propagation of sparks

<u>ducts / vents</u>:

- external temperature elements to automatically shutoff the system when an overheat is detected
- double walled ducting to limit the chance of NEA leakage into the pressurized section of the aircraft
- ventilation to avoid built up of NEA
- oxygen rich vents located away from fuel sources so as to not create a fire hazard
- bonding the tubing of the distribution system to prevent the creation of static electricity at high velocity flow rates of NEA

<u>valves / sensors</u>:

- pressure relief system to avoid fuel tank overpressure

- temperature monitoring sensors to avoid hot air being pumped into fuel tanks and increasing the risk of fuel tank explosion
- rapid shutoff of the shutoff valve by a high flow fuse or similar equipment, near the fuselage penetration, in order to prevent loss of cabin pressurization

general:

- development of confined entry space procedures
- air monitoring system (O2 level)
- system to ensure hot gas is not input into the tanks
- features to prevent icing of components, especially the ASM or water separator/filter
- indication system providing information on how system is operating

Other issues that need to be considered are:

- air inlet and exhaust for compressor and heat exchangers require hull/skin penetration
- potential risk from oxygen by-product
- appropriate space on the aircraft needed to fit the equipment
- potential environmental issues from venting the tanks overboard

d.4) Air separator module

The air separator module is a line replaceable unit and should be easily accessible by maintenance personnel.

The choice of ASM is up to the system designer.

One choice may be a passive permeable membrane system that relies on polymer membranes to separate nitrogen from air.

A second choice may be a molecular sieve system that adsorbs oxygen from the air.

Considerations that should be taken within the design choice are:

- Durability
- Sensitivity to hydrocarbon contamination
- Sensitivity to water contamination

6. Certification Plan / Compliance Demonstration

Any inerting system is an integral part of the fuel system. A certification plan needs to be developed in order to demonstrate the airworthiness of the system itself, including its compatibility with the surrounding systems (fuel, air, …)

This section provides general certification guidance by providing suggestions on what could be included within the certification plan.

a.) Description:

Describe the fuel-tank inerting system design and operation.

The design description should include a description of the type of inerting system chosen, a system schematic, its interface with other aircraft systems including the cockpit, its interface with external services (for instances it needs NEA supplied from a source outside the aircraft).

The operational description should include the flight phases for which the system will be operated.

b.) Safety Assessment:

The applicant should define the safety assessment activities and their interrelationship with other activities within the design approval process.

FAR/JAR 25.1309 and its associated guidance material should be used as the basis of the assessment.

Compliance with FAR 25.901(c) should be demonstrated.

The analysis should identify any maintenance and or flight crew indications and procedures required to maintain aircraft safety as a result of fuel-tank inerting system installation.

c.) Analysis:

Analysis can be used to demonstrate the systems effectiveness and operating characteristics.

The first analysis is the flammability exposure analysis. If the applicant wishes to establish the benefit that the fuel tank inerting system has then the analysis should be done with and without the system installed.

The second type of analysis concerns the system operating characteristics. The analysis may be used to show the predicted effectiveness of the system. Its impact on other aircraft systems and its behavior under critical flight or electrical loading conditions should be evaluated.

A similarity analysis may be done to show the correct functioning of comparable systems or components.

d.) Testing: ground test, flight test and laboratory test

Ground / Flight Testing

A ground and/or flight test program should be established based on the newness of the design concept.

A flight and/or ground test program can be used to demonstrate that the fuel tank inerting system, including the NEA distribution system, is functioning as intended.

Laboratory Testing

Laboratory testing should be used, as required, for component test qualification.

e.) Compliance reports

The type of compliance reports should be provided within the certification plan.

Examples of the types of reports that may be provided are:

- System description and analysis
- System safety analysis
- Ground and flight analysis
- Component qualification reports

7. System installation considerations

Fuel tanks become inert because of the system operation. If the system is not installed and maintained correctly it can become in and of itself a hazard to the aircraft.

The fuel tank inerting system produces (OBGI and OBIGGS) and distributes NEA to one or more fuel tanks and vents the displaced fuel tank ullage overboard.

a.) Distribution system

The NEA distribution system is both external and internal to the fuel tank(s). Its purpose is to deliver NEA to the tanks.

External to the tank

Because NEA is a hazardous substance, design precautions should be taken to avoid and to detect NEA leakage. Design precautions such as double walled pipes, isolation-valves, seals between interfaces and leak detection devices should be considered within the design. The distribution piping should be routed through the non-pressurized portion of the bulkhead in order to minimize the risk of leakage into the cabin.

Internal to the tank

Distribution system should be constructed in order to ensure a homogenous distribution of NEA throughout the tank. Appropriate precautions should be taken to ensure that the tank is not over-pressurized and that fuel does not contaminate the NEA distribution system. The distribution system should be bonded such that static electricity at high velocity flow rates of NEA does not create an ignition source.

b.) Vent system

The fuel tank vent system affects the efficiency of the inerting system.

Open vent system

Virtually all commercial vent-systems are designed to allow ambient air to flow into the tanks due to pressure differences between the tank and ambient.

The inert gas will freely flow out of the vent system. The system design should therefore be sized to accommodate for this loss. For OBIGGS systems, because the tanks are being kept inert all the time, the flow of the inert gas must be sufficient to limit the increase of oxygen content in the ullage due to ambient air influx.

Open, cross-vent flow

Some aircraft types vent the fuel tanks to multiple vent boxes (cross vent flow). This vent arrangement may permit a crosswind to ventilate the tanks with ambient air on the ground and/or in-flight. (FAA flight testing on a B737 showed that this type of system did not retain the NEA under ground based inerting conditions.) The effect of this type of vent should be tested.

Closed vent

Some military aircraft close the vent system with specialized check valves in order to retain inert gas in the fuel tanks. The check valves require a differential pressure to open. This feature adds a level of complexity to the vent system.

If this type of system is used, structural stresses on the wing structure should be carefully analyzed and be accounted for in the basic design. A fuel tank with an open vent will normally have some positive (expanding) or negative (contracting) pressures occurring during climb and descent until the ambient air equalizes with the pressure inside the tank. A closed-vent system exaggerates this effect by requiring the air at the high-pressure area to overcome the check valve's spring.

In a similar manner, a closed-vent system may increase the structural stress due to overflowing fuel from a fuel tank. For example, a fill valve may fail to close allowing a fuel tank to overfill into the vent system. Two-phase flow can develop when this overfill is combined with air pressure being expelled from other tanks. The addition of the backpressure from the check valve's spring will add to the total pressure within the fuel tank.

A check valve that fails closed may cause the fuel tank structure to experience high loads. For example, a check valve that failed closed on the ground would prevent air from exiting during climb resulting in a large pressure attempting to expand the fuel tank structure. A check valve that failed closed in flight would prevent air from entering the tank during descent resulting in the ambient air attempting to crush the tank structure. Redundant check valves would alleviate these stresses.

In addition, if the fuel tank is directly supplying an engine a vacuum will develop within the tank as fuel is consumed unless air can replace the fuel. Redundant check valves would avoid the possibility of engine flameout.

In addition to redundant check valves, a tank pressure indication for the flight crew should be considered. Upon indication, the crew could reduce the climb or descent rate or level off to minimize the structural stress.

c.) Indications: cockpit, maintenance

Indications should be provided such that the user of the inerting system knows the system's condition (operational status). The type of indication should be compatible with the inerting system's design and complexity.

The user of the system should be able to know whether the system is:

– on or off,
– pressurized
– malfunctioning

For automatic systems, a manual override could be considered.

Because the inerting system is considered an added level of protection above that provided by the design features of the ignition system, it is defined by the FAA (AC 25.981-2) as a "safety enhancing" system and is not considered an "essential system". This means that no in-flight indication to the flight crew or any associated flight crew procedures would be needed (except possible if the automatic shutoff of the system fails) for enroute failure of the inerting system.

8. Aircraft Interfaces

The fuel tank inerting system needs to be integrated with the other aircraft systems and need to comply with all relevant 14 CFR part 25 paragraphs.

The fuel tank inerting systems considered within the ARAC FTIHWG showed the systems interface with, at a minimum, the electrical, air and refuel systems. The systems also affect structure and rotorburst considerations.

This section details design considerations for electrical, air and refuel systems.

Electrical system

Inerting systems can place large demands on the electrical system so it is imperative that this be taken into account during the design phase. At a minimum, an onboard system that generates inert gas will require power for a controller, control valves, heat exchanger fans, and sensors. Some designs will require power for precooler fans, additional control valves, and compressors. The power requirements may be upwards of 30 KVA or more depending on aircraft fuel tank size, number of tanks to be inerted, and the desired level of exposure.

For ground operation of the inerting equipment, ground electrical service plugs should be reviewed to ensure they have adequate capacity for the electrical power requirement. The ground service bus should also be reviewed for adequate capacity to handle the inerting system as well as the other systems that are typically operating during ground servicing. In addition, the capacity of the ground power supply should be considered to avoid overload.

For in-flight operation of the inerting equipment, in addition to the items mentioned for ground operation, consideration should be given to emergency power conditions. For example, many aircraft implement "load-shedding" which removes power from nonessential equipment in the event of generator failure. The inerting equipment should not jeopardize safe flight so system designers should consider "shedding" this equipment. Design items that should be included in this evaluation are: fleet-level exposure to a non-inert, flammable fuel tank; availability of power from the remaining generator(s) when one generator becomes inoperative; cost effectiveness of upgrading the power system to larger generator capacity; and cost effectiveness of "shedding" other nonessential equipment.

Engine bleed air system

Onboard systems that separate nitrogen from air require a source for that air. Some aircraft will elect to use engine or APU bleed air as the source.

Membrane and PSA separators generally require fuel vapor and oil to be separated from the bleed air prior to entering the separator. Water and water vapor will also adversely affect PSA separators, requiring a water separator for removal.

Environmental control systems and potable water systems also rely on bleed air for operation. The environmental control system regulates it's demand for bleed air. A regulator failure can cause pressure surges in the system, which may adversely affect the inerting system. Sufficient analysis and testing should be performed to ensure the interaction between the environmental and inerting systems (and other systems drawing bleed air) don't pose a safety hazard to the aircraft or engines in the event of component failures.

Cabin pressurization system

Some aircraft may supply the air separators by compressing cabin air in lieu of, or in addition to, the engine bleed air supply. Another option is to compress engine bleed air when it's available and use compressed cabin air at other times.

Filters

The air separator module will benefit from an air filter to keep out small particles. The compressor may require a filter to keep large particles from jamming the rotor possibly causing a rotor hazard or flammability hazard.

Water separator

PSA modules are sensitive to moisture and will need to be dried once wetted. This can adversely affect system performance and should be avoided by the addition of a water separator upstream of the module(s).

Isolation valve and high-flow fuse

An isolation valve, or another means to shutoff flow, will prevent system operation during failure conditions. For example, when one of the air conditioning packs has failed and the air supply to the cabin is just sufficient for the passengers, the inerting system must be shutoff. In addition, a duct rupture downstream of the valve could quickly evacuate the cabin. This can be prevented by incorporating a "high flow" fuse that closes when the air flow exceeds the needs of the inerting system.

Redundant check valves (to avoid fuel fumes in cabin)

The inerting system couples the cabin and fuel tanks with a system of plumbing. FAR 25.967(e) requires the cabin to be separated from fuel tanks via a fume proof and fuel proof enclosure. Typically redundant check valves in series are employed in plumbing systems to prevent fumes or fuel from entering the cabin.

Refuel systems

Inerting systems operated on ground should be compatible with the refuel system, so as to avoid overpressure of the fuel tanks and to not interfere with the gauging system and the shutoff system.

If ground based inerting is used, the ground connection coupling should be to the defined industry standard.

9. Continued Airworthiness/Maintenance Considerations

The inerting system is part of the aircraft installation and therefore should meet the requirements of FAR §25.1529.

Because nitrogen is a hazardous substance, maintenance procedures should be defined in order to meet OSHA confined space requirements (OSHA No. 1910.146). Placards and environmental monitoring systems should be put in place in order to minimize the risk to the maintenance personnel.

The appropriate warning information should be included in the Maintenance Manuals. Particular attention should be paid to the ventilation systems.

10. Nitrogen Enriched Air (NEA): Precautions to Respect

Nitrogen and other inert gases are not normally dangerous but when used in confined spaces they can quickly create oxygen deficient atmosphere that can be deadly. Nitrogen is especially hazardous because it cannot be detected by human senses and can cause injury and death within minutes. In the US at least 21 people have died in 18 separate accidents between 1990 to 1996 involving the use of nitrogen in confined spaces, even with strict health and safety procedures in place. On the average, work in confined spaces kills 15 people every year in the UK across a wide range of industries, from those involving complex plant through to simple storage vessels. In addition, a number of people are seriously injured. Those killed include not only people working in the confined space but those who try to rescue them without proper training.

The health risk to ground and maintenance personnel servicing the aircraft employing nitrogen inerting technology is present not only in the fuel tanks themselves but in the location of the nitrogen generating equipment. Wherever possible such equipment should be located outside the pressure hull, however, this is not possible on the majority of production aircraft. Therefore, it will be necessary to ensure that safety system and procedures are in place to protect the aircraft and personnel working in and around them.

More detail concerning confined spaces can be found in reference 8.

11. Evaluation of the Effects on Emissions

Inerting with NEA causes additional VOCs (volatile organic compounds) to be displaced from the fuel tank. The increase in VOCs depends on the tank size and the amount ullage space (fuel quantity present in the tank).

Today, there are no 14 CFR regulations controlling fuel tank vent exhaust. However, some airports with the US and foreign airports may have local restriction on VOCs.

If these restrictions exist, then an assessment of the VOC content may need to be initiated along with a vapor recuperation system.

12. Master Minimum Equipment Assessment

The FAA state in AC 25.981-2 that an inerting system is not a flight critical system and that airplanes may be dispatched with the system inoperative for short periods of time, provided the overall exposure to flammable vapors, including dispatch with the system inoperative, meets its flammability requirements.

The standard industry method should therefore be used to propose MMEL relief, along with a proposal stating the conditions under which the system can be inoperative

ATTACHMENT 2
GUIDANCE MATERIAL - FUEL TANK INERTING SYSTEM - OPERATION AND MAINTENANCE

Purpose

The purpose of this guidance material is to provide advice in obtaining approval of a fuel tank inerting program.

A fuel tank inerting program is only needed if a fuel tank inerting system is installed on an aircraft.

Background

This guidance material was created by the FTIHWG as part of its operational regulatory assessment of fuel tank inerting systems. A fuel inerting system is installed to render the fuel tank environment non-flammable.

The background section should be expanded if this guidance material is ever made into an Advisory Circular.

Related Material

List other applicable ACs and industry standards including health and safety standards.

The FARs that would be referenced here would depend on the type of inerting system certified on the aircraft.

The references in the design guidance material could be used as applicable.

Other references to add, if determined applicable at the time of the Advisory Circular publication are:

3.1 (National Fire Protection Agency)NFPA 410 chapter 4 Aircraft Fuel Maintenance

3.2 OSHA Standard Number 1910.146 - Permit-required confined spaces subpart J, General Environmental Controls

3.3 Confined Space by Eric LeBreton - Canadian Transport Emergency Centre , Canutec Web site

Definitions

The type of definitions may be the same as those listed in the design guidance material. Specific definitions related to the operation of a NEA inerting system may be added based on an actual system design..

a). ASM: Air separator module - either a passive permeable membrane system that relies on polymer membranes to separate nitrogen from air or a molecular sieve system that adsorbs oxygen from the air

b). Center wing tank: A fuel tank located in the aircraft's wing box but located within the fuselage of the aircraft.

c). Flammable: Flammable, with respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding. (14 CFR Part 1, Definitions).

d). Flammability exposure: "Exposure" refers to the mission time where a combination of items in a fire triangle, required to obtain combustion, exists. The fire triangle consists of oxygen, flammable fuel, and an ignition source. If any one of these is removed, combustion will not occur.

Note: Because fuel flammability varies with fuel temperature, fuel type and fuel altitude, exposure may vary based on the heat transfer characteristics of a fuel tank. For instance, any fuel tank that presents a large surface area to the airstream could have a smaller exposure than a fuel tank within the fuselage.

e). Flammability range: The pressure (i.e., altitude)/temperature domain where the fuel vapor/air mixture is flammable. This domain is dependent on the type of fuel used.

f). Fuel air ratio (FAR): The ratio of the weight of fuel vapor to the weight of air in the ullage.

g). Fuel tank: An aircraft volume containing fuel. Tanks contain both liquid fuel and, in the vapor space or ullage space, a fuel vapor/air mixture, with some water vapor, depending on the relative humidity in the tank.

h). Fuel types: Different fuels are approved for use in turbine powered airplanes. The most widely used fuel types are JET-A/JET-A1 and JET-B (JP-4), per ASTM Specification D1655-99, "Standard Specification for Aviation Turbine Fuels." The approved fuel types for a given airplane type are listed in the Airplane Flight Manual (AFM). Each fuel type has its own properties; those directly related to flammability are "flash point" and "distillation" characteristics. Property differences can occur in a given fuel type as a result of variations in the source crude oil properties and the refining process used to produce the fuel.

i). Heated fuel tank: Fuel tanks that experience a rapid rise in temperature due to the adjacent system equipment.

j). Inert fuel tank: Fuel tank inerting, as applied to aircraft fuel tanks, can be defined as the inclusion of a gas, in the ullage prior to ignition of the vapor, that will suppress that ignition, independent of the fuel air mixture.

k). Inert gas: A gas that will not oxidize. In fuel tanks, the ullage in considered inert when the O2 concentration is approximately 10% or less (unless future data shows otherwise), when nitrogen is used as the inert gas.

l). Lean Fuel Vapor/Air Mixture: A fuel vapor mixture that has insufficient concentration of fuel molecules below that which will support combustion.

m). NEA: Nitrogen enriched air - a gas with nitrogen purity of 90-98%.

n). Operational time: The time from the start of preparing the airplane for flight, (turning on the auxiliary power unit (APU) /ground power, starting the environmental control systems etc.,), through the actual flight and landing, and through the time to disembark any payload, passengers and crew.

o). Rich Fuel Vapor/Air Mixture: A fuel vapor/air mixture that contains a concentration of fuel molecules above that which will support combustion

p). Ullage or ullage space: The volume within the tank not occupied by liquid fuel.

q). Ullage washing: Use of inert gas to dilute the air above the fuel (ullage).

r). Unheated fuel tank: a fuel tank that is not heated

(AC 25.981-2 definition - A conventional aluminum structure, integral tank of a subsonic transport wing, with minimum heat input from the aircraft systems or other fuel tanks that are heated.)

s). Wing tank: A fuel tank located within the aircraft's wing.

Note: Generally, any tank that presents a large surface area to the airstream could be considered to have the same exposure as a wing tank. For example, fuel tanks in the horizontal or vertical stabilizer, wing-mounted pods, or externally-mounted fuselage or fairing tanks.

Fuel Tank Inerting Program Elements

a.) Management plan: a detailed description of the operational responsibilities and procedures associated with the implementation and conduct of the certificate holder's "fuel tank inerting program".

Note: the management plan may differ depending on the type of inerting system.

b.) Establishment of inerting timetables/dispatch conditions: (design dependent) a set of timetables associated to the effectiveness of the inerting process. These timetables may need to associate inerting with arrival or departure time, ambient air temperature, etc.. For GBI there may be a "validity time". Associated limitations need to be defined, provided and used by the certificate holder's personnel.

c.) Establishment of inerting operational procedures: Aircraft inerting procedures and responsibilities need to be defined - aircraft arrival, dispatch, maintenance

d.) Establishment of maintenance program: a maintenance program and associated precautions

e.) Training: Initial and recurrent ground training and testing for all affected personnel (e.g. aircraft dispatchers, ground crews, contract personnel, flight crew, etc.) need to be put in place. The type of training will be system dependent (GBI / OBIGGS)

f.) Health and Safety Standards: Health and safety standards will need to be revised to include the use of nitrogen.

Note: Emissions: Local airport emission requirements may have to be evaluated against the possible excess of fuel tank vent emissions (VoCs) resulting from inerting. (Emission effects will be design and aircraft dependent.)

Management plan

Purpose of the plan is to ensure that operational control (ensure proper execution of a fuel tank inerting program).

The plan needs to be submitted and approved by the FAA. The plan includes :

- the manager responsible for the overall fuel tank inerting program,
- this manager's organization including the individual group (task) managers, their functions and responsibilities against each applicable FAR
- the specific elements covered by the plan. The elements should either be detailed within a specific document or be cross referenced to other internal documents

Specific elements for which the management organization needs to be detailed and approved are:

a) Operations:

The management position responsible for ensuring that all elements of the inerting program are developed, integrated and coordinated needs to be identified. This person is responsible for ensuring that the plan and program are circulated and implemented throughout the organization to those people who have duties, responsibilities and functions to accomplish within the overall program plan. The plan should consider the following:

- for each airport where fuel tanks will be inerted, determine who will be responsible for operational procedures linked to inerting
- specify the functions, duties, responsibilities, instructions and procedures to be used by flight crew members, air dispatchers and management dispatch personnel for safely accomplishing inerting (ground procedures) and dispatching an aircraft with an inert fuel tank(s)
- if inerting is linked to a "validity time", then define a detailed procedure to re-perform the fuel tank inerting and re-dispatch the aircraft. Coordination with the ATC, ground operation personnel, fight crewmembers, dispatchers or flight followers, contract personnel and management personnel should be detailed. Consideration of whether GBI can be done with passengers on board needs to be accounted for in the final plan.

- Ensure oversight of the program

b) Maintenance:

Identify who is responsible for ensuring that enough trained and qualified personnel, as well as adequate facilities and equipment are available at each airport where fuel tank inerting operations are expected. The management plan should:

- ensure that all necessary maintenance elements of management plan and fuel tank inerting program have been developed (in accordance with the aircraft type and manufacturers recommendations), integrated and coordinated.
- Detail the duties, responsibilities and function of this plan and ensure that this has been circulated and implemented by the persons assigned to perform the specific duties.
- Ensure management oversight of the program
- Incorporate a detailed description of the maintenance portion of the fuel tank inerting program in the certificate holder's manuals for use and guidance of maintenance, ground, flight crew, contract and management personnel.

c) Aircraft Servicing on Ground

The interface of fuel tank inerting procedure with the other pre-departure activities needs to be detailed and diffused. Management of activities such as refueling, baggage/cargo loading, catering services, toilet servicing. etc. need to be integrated and coordinated with the fuel tank inerting activity.

Precautions, including the dangers of what could happen if these precautions are not respected, that need to be taken by persons providing these other interface services should be developed, diffused and implemented.

Establishment of inerting timetables/dispatch conditions

Certain design features - fuel tank and vent system or the inerting system - may have certain limitations. The limitations may be related to time, outside ambient temperatures or fuel tank loading.

These limitations are design dependent and will be defined by the OEM. Not all designs will have limitation conditions!

Operational procedures should be established in order to ensure that these limitations are respected.

If one of these limitations exists, then the certificate holder's program should define operational responsibilities and should develop procedures to instruct the flight crew, aircraft dispatchers, flight followers, and maintenance and ground personnel on the condition limitations, evaluation of these limitations and the resultant action to take. The procedures should include gate procedures, communication procedures with the ground and flight crew and coordination with ACT.

The limitations should be supported by the manufacturer's design data.

a) "Validity Time"

For ground based inerting, the effect of inerting may be time limited; that is the fuel tank ullage may only stay inert for a certain period of time.

For on board inerting, the inerting system may have to be started a certain minimum time prior to dispatch. If its operation is interrupted (or stopped), then the effect of inerting may be time limited

The "validity time" clock starts from the time the inerting process is completed and stops when the aircraft pushes back from the gate.

Procedures to determine the action if the "validity time" is exceeded shall be detailed and defined in the certificate holder's program.

b) Outside Air Temperature

Fuel tanks may only have to be inerted when the ambient temperature is above a certain limit. This limit is dependent on the fuel tank design and shall be provided by the manufacturer.

A procedure, and the associated responsibility definition, should be put into place to define when inerting is needed based solely on outside air temperature. The procedure should define the effect of the increase/decrease of temperature with time of day and the projected weather forecast.

c) Fuel Tank Loading

Fuel tank inerting may only be needed if the fuel tank is being dispatched not full. This limit is dependent on the fuel tank design and shall be provided by the manufacturer.

A procedure, and the associated responsibility definition, should be put into place to define when inerting is needed based solely on fuel tank loading.

d) Multiple conditions

A multiple set of conditions may need to exist in order to forego fuel tank inerting. The manufacturer shall define these conditions.

A procedure, and the associated responsibility definition, should be put into place to define when inerting is needed. Particular attention should be paid to the decision criteria used and the communication of the decision.

Operations Manual

a) General

Operational procedures regarding the fuel tank inerting system install on the aircraft type should be approved as part of an operator's initial operational manual approval or as a revision to that manual.

A quality assurance program should be put into place in accordance with the management plan and applicable FAR regulations.

b) Operating Procedures

Specific attention should be paid to the impact that fuel tank inerting has on the flight preparation instructions and the ground handling instructions. Each aircraft manufacturer (or fuel tank inerting system supplier) should provide the operator with system operating instructions / recommendations. These instructions may vary depending on the type of fuel tank inerting system installed.

Flight preparation procedures may be impacted, if the operator needs to determine whether or not the fuel tank needs to be inerted. The decision criteria, developed under section 7.0, should be used, as appropriate.

Ground handling instructions should include,

- Safety precautions to be taken when inerting (GBI)
- Changes that inerting brings to current procedures or precautions, such as fuel mixing precautions
- Embarking and disembarking passengers while the fuel tanks are being inerted
- Crew procedures that will ensure the proper precautions are taken to avoid NEA vapors from entering the cabin while passengers and/or flight crew are on board. (Manufacturer recommendation - design dependent.)

- Safety precaution on the ramp - identification of areas that should be avoided by passengers/flight crew embarking / disembarking /inspecting the airplane due to the presence of NEA
- Start-up procedure (OBIGGS)
- Communication instructions

It is noted that the Airport Handling Manual may need to be updated due to the presence of an inerting system.

The operator may opt to create a dedicated fuel-tank inerting section within its ground handling procedure section of the operating manual. The management plan (section 6.0), the timetable/dispatch conditions (section 7.0), fuel tank inerting procedures, communication procedures and cockpit preparation procedures could be discussed within this dedicated section.

c) <u>Minimum Equipment List (MEL)</u>

The presence of a fuel tank inerting system may impact the operator's MEL.

As with other systems, the MEL for a fuel tank inerting system should be developed based on the manufacturer's recommendations and the operator's operational policies and national operational requirements.

The MEL determination will be made considering that an acceptable level of safety is maintained with this system non-operational. Specific compensating factors, which may allow the acceptable level to be maintained are: appropriate operating limitations, transfer of the function to another system, alternative means to produce a similar effect.

The Technical Log will be used to record when and why the aircraft's fuel tank inerting system is dispatched on MEL. Any operational limitations should also be noted. The rectification of this MEL item should also be recorded in the Technical Log and include the details of the rectification as well as a statement that the MEL item has been removed.

<u>Maintenance Manual</u>

a) <u>General</u>

Maintenance procedures for the fuel tank inerting system installed on the aircraft type should be approved as part of an operator's initial maintenance manual approval or as a revision to that manual.

A quality assurance program should be put into place in accordance with the management plan and applicable FAR regulations.

b) <u>NEA Handling Policies</u>

Special emphasis should be put on the development and implementation of all procedures and precautions implemented because of inerting and in particular - handling of NEA. This includes:

- Fuel tank purge procedures - open and confined spaces
- Fuel tank entry procedures
- Precautions around fuel tank vents
- Precautions around NEA supply trucks
- Recuperation of fuel tank vent gas (recuperation of VoCs)
- Special clothing or protection gear
- emergency care in case of asphyxiation by NEA

- NEA handling procedures

c) NEA specifications / characteristics

GBI - The characteristics / specification of the NEA that will be used to inert the fuel tanks should be defined and recorded in the appropriate manuals.

OBIGGS - Particular attention should be paid to he efficiency (service life) of the air separator module (nitrogen producing capability), noting that nitrogen will not be produced if this component does not perform its intended function.

Training Requirements

All persons involved in the maintenance, dispatch and operation of the aircraft need to receive initial and recurrent training on the functioning, operation and procedures associated to the fuel tank inerting system, as well as the danger of nitrogen if these procedures are not respected. These persons are:

- Flight crew
- Dispatcher
- Ground personnel
- Contractor
- Maintenance personnel

The training syllabi should be adapted to each discipline and to the type of inerting system installed on the aircraft. However, each course should include:

- A description of the inerting system, including its purpose
- The benefits and potential dangers of the system
- Hazards and handling of NEA
- A description of the management plan and communication process - overall process of who is involved and the specific role of the discipline being trained
  - The specific requirements of the program and the duties, responsibilities and functions detailed in the program
- Emergency care procedures if nitrogen asphyxiation occurs
- A test or qualification examine

For maintenance personnel, specific attention should be placed on the dangers of nitrogen and precautions to take when working in confined spaces.

The operator should ensure that its initial and recurrent training program for each discipline is described in detail and documented in the company's training requirements.

Health and Safety Standards

The operator's health and safety standards should be updated to include working with NEA. Specific areas may include but are not limited to:

- NEA handling
- Emergency care procedures

- Working in confined spaces
- Identification of health risks
- Identification of protective clothing

Emissions

Certain countries may have national regulations concerning the amount of VOCs released into the atmosphere.

Each operator must assess the environmental impact using the manufacturer emissions estimation and the national environmental regulation.

The result of this assessment may lead to the mandatory recovery of the VOCs or the prohibition of fuel tank inerting within the national airspace. If this happens ground or flight procedures would have to be adopted accordingly and recorded within the management plan and the manual. Training courses would also need to incorporated these differences within the affected disciplines' course.